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Tropical Fruit Wines: Health Aspects

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Abstract: Several tropical and subtropical fruits although they differ in shape, colour, taste and nutritive values and provide numerous health benefits. These fruits are often very rich in anti-oxidants such as luteins, carotenes, anthocyanins, phenols, tocopherol, etc. Examples of such edible tropical fruits are jackfruit, cashew apple, mangoes, papaya, pineapple, litchi, guava, bael, banana, pomegranate, tendu, jamun and palm. Most of these fruits ripe within a very short period in a year, usually leading to an over abundance when harvested. These fruits are mostly consumed fresh, but large quantities of harvested fruits are wasted during peak harvest periods, due to the high temperature and humidity existing in tropical climate, along with poor post-harvest handling, poor storage facilities and microbial spoilage. Therefore, wine making from such ripe fruits or their juices is considered as an alternative of utilizing surplus and over- ripen fruits for generating additional revenues for the fruit growers as well as preservation. This chapter summarizes current knowledge on wine making from tropical fruits and health aspects; mainly, nutritional, therapeutic, immunological and antioxidant properties.

Key words: Wine · Red Wine · White Wine · Pink Wine · Tropical Countries · Sub-Tropical Countries · *Saccharomyces cerevisiae* · Fermentation · Tropical Fruits · Health Aspects

INTRODUCTION

Tropical and Sub-tropical countries are the largest producers of fruits in the world. Fruits are among the most important foods of mankind as they are not only nutritive but are also indispensable for the maintenance of human health. Fruits both in fresh as well as in processed forms improve the quality of our diet as well as provide essential ingredients like vitamins, minerals, carbohydrates and anti-oxidants. Tropical countries possess a wide diversity of fruits with many possibilities of commercial exploitation; some of them are considered exotic and rare. Major tropical fruits like mango [1], jackfruits [2], bael [3], jamun [4] and banana [5] could enhance local or international markets by appropriate utilization processes and fermentation remains as a technological attempt of such utilization [4, 6].

Fermentation is a viable technique in the development of new food products with modified physico-chemical and sensory qualities especially flavor and nutritional components. Alcohol, acetic and lactic acid are important for imparting quality in fermented food and beverage production [7]. Out of these, alcoholic fermentation is widely employed for the preparation of beverages in which ethanol is the major constituent. Fermented alcoholic beverages have been known to mankind from time immemorial. These are divided into three general categories for taxation and regulation of production, i.e., beers, wines and spirits (distilled beverages) such as whisky, rum, gin, vodka, etc. Beer is made by fermentation of starch combining yeast and malted cereal starch, especially barley, rye, wheat or blend of several grains and usually flavored with hops. It contains 4 to 8 per cent 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 per cent.

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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 influence the quality of the finished product. The composition and concentration levels of the by-products can vary widely [8]. There is an abundance of exotic tropical fruits in Tropical and Sub-tropical countries with the potential to be used by the food industry. One possible use of these fruits is in the production of wines from various tropical fruits. There are many studies in the literature that demonstrate the feasibility of using fruits other than grapes to produce alcoholic beverages. There are several Tropical and Sub-tropical fruits with the potential for use in the production of wines.

Wine, made from a variety of fruit juices by the fermentative action of selected yeast, is adapted to an ageing process handed over from generation to generation. Traditionally, wine was produced from grapes which are mostly available in Europe, North America or North and South Africa [9-12] through fermentation by yeasts, producing significant quantity of ethyl alcohol depending upon the variety and techniques used. Different types of table wines e.g. dry, sweet and sparkling wines having alcohol content 8 to 15 % by volume are popular ones throughout the world. Wine has prominent health benefits in controlling cardiovascular diseases. Despite numerous research efforts, wine from fruits other than grapes has not been vastly commercialized and gained popularity among the consumers. However, exploring the scope of wine fermentation from locally available fruits and establishment of wineries will reduce post harvest losses of surplus fruits and lead to agricultural diversification and employment generation in developing countries.

Fermentation: Fermentation is a biotechnological process 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. Industrial fermentation processes are conducted with selected microorganisms under specified conditions with carefully adjusted nutrient concentrations. The products of fermentation are many: alcohol, glycerol and carbon dioxide which are obtained from yeast fermentation of various sugars. Butyl alcohol, acetone, lactic acid, monosodium glutamate and acetic acid are products of bacterial action; citric acid, gluconic acid, antibiotics, vitamin B_{12} and riboflavin are some of the products obtained from mold fermentation.

Fermented fruit wines are popular throughout the world and in some regions it makes a significant contribution to the diet and income of millions of individuals. The use of pineapple for the production of wine could create employment, income generation for farmers and address the post harvest losses associated with glut on the local market in countries like Benin [13].

Freezing of fruits and vegetables is not economically viable at the small-scale because of capital expenditure on machineries, installation and energy consumption. In contrast, fermentation requires very little sophisticated equipment, either to carry out the fermentation or for subsequent storage of the fermented product [14].

***Saccharomyces cerevisiae* and Alcoholic Fermentation:** Yeasts are of great economic importance. Yeasts, especially different strains of *Saccharomyces cerevisiae* have long been used for the production of alcoholic beverages, solvents and other chemicals. Yeast are a unicellular fungi or plant-like microorganism that exists in or on all living matter i.e. water, soil, plants, air, etc. 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 yeast strain most commonly used for baking is *Saccharomyces cerevisiae*. The scientific name *S. cerevisiae* means 'a mold which ferments the sugar in cereal to produce alcohol and carbon dioxide'.

Wine Fermentation: Wine making is one of the most ancient of man's technologies and is now one of the most commercially prosperous biotechnological processes [16]. The technique of wine making is known since the dawn of civilization and has followed human and agricultural progress [17]. 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 [18]. In ancient China, fermented beverages were routinely produced from rice, millet and fruits [19]. 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 [18]. Many of the polyphenols and other bioactive compounds in the source materials are bonded to insoluble plant compounds. The wine making process releases many of these bioactive components into aqueous ethanolic solution, thus making them more biologically available for absorption during consumption by human beings.

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 [19]. 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 industry uses a 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, but also to far off places [20]. 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 [21].

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 colour, taste, aroma, ecological production, guaranteed origin, quality and sensory perceptions offered by the complex combinations of hundreds of components present in wine [22]. No food or beverage is worth producing, distributing or marketing without having an approximate idea that its sensory quality is accepted by consumers [23]. Apart from grapes, there are many other fruits available that can be used as substrates for wine making. Amongst various fruits, grapes are the most technically and commercially used as substrates for wine making. The impact of the model plant grape is relevant, hence genetic and molecular studies on this plant species have been proved to be very successful in wine making [24].

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 [25]. Both clinical and experimental evidences 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 are found particularly in red grape wine [26, 27]. The phenolic acids can scavenge free radicals and quench reactive oxygen species (ROS) and therefore provide effective means of preventing and treating free radical mediated diseases [28]. Also, wine polyphenols can lead to the modulation of both oral and gut microbiota [29].

Classification of Wine: A typical wine contains ethyl alcohol, sugar, acids, higher alcohols, tannins, aldehydes, esters, amino acids, minerals, vitamins, anthocyanins, minor constituents like flavoring compounds, etc. [30]. Depending upon the various attributes such as cultivar, stage of ripening of fruits, chemical composition of juice, use of additives to the must, vinification techniques and ageing of wine, the alcohol and sugar content, the wines are classified as natural wines (9-14 % alcohol) and dessert and appetizer wines (15 - 21 % alcohol) [25]. Dry wine, sweet table wine, specialty wine, champagne, muscat and burgundy wines are natural wines while sweet wine, cherries, vermouth and port wines are regarded as dessert and appetizer wines.

The most famous types of wines are red and white wines, followed by rosé and sparkling wines. There are other wine specialties around the world, such as the Portuguese Port Wine, a very rich flavor, often used by chefs in their signature dishes. Many types of wines can be divided into several groups, which are easy to remember. Depending upon product manufacturing all wines can be classified as grape wine, fruit wine, berry wine, vegetable wine, plant wine, raisin wine, etc. Grape wine is made exclusively from grapes and during the production process prohibited from using any other materials (exception is made only for sugar and oak barrels). Fruit wines are fermented alcoholic beverages made from a variety of base ingredients other than grapes; they may also have additional flavors taken from fruits, flowers and herbs. These types of wines are made from pear, apple, banana, papaya, mango, jackfruit juice etc. Cherry wine is produced from cherries, usually those cherries that provide sufficient acidity to wine. Plant wine is produced from juice of trees like maple, birch, melons, watermelons and other garden plants such as rhubarb, parsnips and rose petals. Raisin wine is made from dried grapes (raisins). Multisort wine is produced by mixing different kinds of grapes and wine materials [31].

Red Wine: Red wine is made from red grapes, which are actually closer to black in color. There are many different types of red wines. This is considered to be the most

Table 1: Characteristics of different types of Red wine

Type of Red Wine	Common Aromas	Mouth feel	Acidity	Region of Origin
Barbera	Blackberry, Black cherry, Raspberry and Plum.	Smooth	High	Italy, Argentina and California.
Cabernet Sauvignon	Dark berries, Cassis and Cedar wood	Smooth with a coarse finish	High	France, Italy, Australia and California.
Malbec	Plum, Black pepper and Black berry.	Full, Rich	Medium	France and Argentina.
Merlot	Plum, Cherry and Floral aromas.	Soft	Medium	France, California, Italy, Washington and Chile.
Syrah/Shiraz	Black pepper and Black berry.	Smooth, Round	Medium to High	France, Italy, Australia, California, Washington and South Africa
Pinot Noir	Baked cherry, Plum and Damp earth.	Smooth with crisp finish	Medium to High	France, Oregon, California, New Zealand and Australia
Zinfandel	Blackberry, Boysenberry and Plum.	Smooth	Medium	California

Source: www.foodservewarehouse.com

Table 2: Characteristics of different types of White wine

Type of White Wine	Common Aromas	Mouth feel	Acidity	Region of Origin
Chardonnay	Tropical fruit, Pineapple, Apple, Lemon and Oak.	Smooth	High	France, California, Washington, Oregon, New York, Australia, New Zealand and South Africa.
Gewürztraminer	Tropical fruit and Spice.	Very smooth	Low to Medium	France, Germany, Washington, California and New York.
Muscat/Moscato	Peach, Pear and Citrus.	Full bodied, Smooth and Creamy	High	France, California, Washington, Oregon, New York, Australia, New Zealand and South Africa.
Pinot Grigio	Grape and Pear.	Bright, Smooth and Light	High	Northern Italy, Spain, France and California.
Reisling	Peach, Citrus and Apple.	Light, Round.	Low to Very High	France, California, Washington, Oregon, New York, Australia and New Zealand.
Sauvignon Blanc	Green fruits, Grass herbs, Gooseberry, White asparagus, Ripe fruits and Nuts.	Crisp	High	France, California, Washington, Oregon, New York, Australia and New Zealand.
Semillon	Ripe fruits, Nuts, Honey and Orange peel	Smooth	Medium	France, Washington and Australia
Viognier	Apricot, Fruits and Floral species.	Smooth	Low	France, Oregon and California.

Source: www.foodservewarehouse.com

classic in the kingdom of wines, mixing the delicious red grapes with a wide range of aromas, from Oak to eucalypti, chocolate or even mint hints. The juice from most black grapes is greenish-white; the red colour comes from anthocyanin pigments present in the skin of the grape. The Table - 1 give the characteristics of different types of Red wine.

White Wine: White wine is not exactly white; it is often yellow, gold or straw coloured, depending on whether it includes the skin of the grape or just the juice. White wine can be made by the alcoholic fermentation of the non-coloured pulp of green or gold coloured grapes or from selected juice of red grapes, produced in Europe and numerous other places such as Australia, California, New Zealand and South Africa and so on. It is treated so as to maintain a yellow transparent colour in the final product. White wines often taste lighter, crisper and more refreshing than a red wine and so they often gain popularity during warmer months of the year. White wines are typically served alongside white meats and fish. The Table - 2 and give the characteristics of different types of White wine.

Pink Wine: Pink wine having a light pink color, grape skin removed immediately after the start of the fermentation process. These wines are made from a mixture of "black" and "white" grapes, using the technology of producing white wines. Classification of wines by the sugar and alcohol implies their division in dining rooms and fixtures.

- Table wines are dry (sugar and 0.3 % alcohol-9-14 %), semi-dry (sugar - up to 0.5-3 % alcohol - 12.9 %) and sweet (sugar - up to 3-8 % alcohol - 12.9 %).
- Fortified wines are of the following types: strong (sugar - upto 1-14 %, alcohol-17-20 %), dessert sweet (sugar - upto 5-12 %, alcohol-14-16 %), sweet (sugar - to 14-20 % alcohol-15-17 %), liqueur (sugar - up to 21-35 %, alcohol-12-17 %), flavour (sugar-upto 6-16 %, alcohol-16-18 %).

Wine Making Technology: Fruits such as banana, cucumber, pineapple and other fruits are used in wine production [32-35]. Using species of *Saccharomyces 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 help to preserve the wine [36-38]. Yeasts from other sources such as palm wine has also been used [39] in the production of fruit wine.

Wine making involves mainly three categories of operations, *viz*., pre-fermentation, fermentation and post fermentation operations [40-42]. 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 wine making, 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 wine making.

Tropical Fruits: There are some soft fruits from both temperate and tropical regions whose pigment stability and flavor profiles match those of wine from grapes [43], but suffer from the lack of intensive research and development in the way to commercial production [44, 45]. The tropical fruits are highly perishable, being susceptible to bacterial and fungal contamination, thus leading to their spoilage, mechanical damage and over ripeness [46]. Hence, these fruits are difficult to keep for long and are utilized either as fresh or processed into juice and specialty products [47-49].

Tropical Fruits can be classified based on acidity, bearing, size and seed type. The classification based on acidity comprises four sets of fruits: alkaline, sub-acidic, acid and melons. Alkaline fruits have a characterizing sweet taste and high sugar content while acid fruits have sour taste and high concentration of citric, malic and oxalic acids. Sub- acidic fruits have a taste somewhat between sweet and sour. Melons have a distinct feature of sweet taste with high moisture content. Fruit-bearing plants are also categorized in several ways. Among the tree fruits are the citrus fruits while vine fruits are grapes and kiwi. Berries are classified as bush fruits. Herbaceous fruits have minimal or no woody tissue. Tender, nut, pome and stone fruits are another way of classification. Tender fruits comprise of pineapple, pomegranate and jackfruit etc. Nuts such as pequi and pitomba have a hard outer shell surrounding an inner edible tissue that is consumable. Pome fruit bears a fleshy fruit surrounding a central core of seeds and mainly consists of apple, acerola, mango, jamun, papaya, guava, melon, sapota and pinha etc. Stone fruit bears a single pit in the centre, they are commonly referred as stony fruits (avocado, cherry and jamun).

Wine from Tropical and Sub-Tropical Fruits: The techniques used for the production of fruit wines closely resemble those for the production of wines made from white and red grapes. The differences arise from two facts. It is somewhat more difficult to extract the sugar and other soluble materials from the pulp of some fruits than it is from grapes and secondly the juices obtained from most of the fruits are lower in sugar content and higher in acids than is true for grapes. As a solution to the above mentioned problems, the use of specialized equipment to thoroughly chop or disintegrate the fruits such as berries, followed by pressing to extract juice from the finely divided pulp, solves the first problem. The second problem is solved by the addition of water to dilute the excess acid and the addition of sugar to correct the sugar deficiency [30]. The list of fruits which were used as substrates for wine fermentation and the microorganisms used for wine production are given in Table - 3.

Some of the notable tropical fruit wines that have gained some amount of popularity indigenously are guava [74], jackfruit [75] and litchi [76]. There are only a few studies on fermented beverages from tropical fruits. Onwuka and Awan [77] produced a sparkling wine from overripe banana and plantain with alcohol content of 11.3 %, pH of 4.1, 1.02 g L^{-1} tartaric acid for TA and 8.0 °Brix for TSS. Carreno and Aristizabal [78] also carried out the fermentation of plantain to produce a wine having alcohol content of 8 %; 0.65 g L^{-1} tartaric acid for TA and 9.6 °Brix for TSS. Akubor *et al.* [51] obtained a different composition (pH was 3.3, 0.85 g L^{-1} tartaric acid for TA, 5 % alcohol, 4.8 °Brix for TSS and 0.04 g 100 ml^{-1} residual sugar) after a fermentation process to produce banana wine. In comparison to a German grape wine which was used as a standard reference for flavor, taste, clarity and overall acceptability, there were no significant ($p = 0.05$) differences. Kinnow, a hybrid of *Citrus nobilis* and *Citrus delicosa* contributes towards a major fruit production in Tropical and Sub-tropical countries but has a poor shelf-life [79].

Table 3: Fruits and microorganisms involved in fruit wine fermentation

Common Name	Scientific Name	Family	Fermentative Microorganisms	References
Apple	*Malus domestica* Borkh.	Rosaceae	*Saccharomyces cerevisiae* CCTCC M201022	[50]
Bael	*Aegle marmelos* L.	Rutaceae	*Saccharomyces cerevisiae*	[43]
Banana	*Musa sapientum* L.	Musaceae	*Saccharomyces cerevisiae*	[51]
Black raspberry	*Rubus occidentalis* L.	Rosaceae	-	[52]
Cacao	*Theobroma cacao* L.	Malvaceae	*Saccharomyces cerevisiae* UFLA CA 1162	[53]
Carambola	*Averrhoa carambola* L.)	Oxalidaceae	*Saccharomyces cerevisiae*	[54]
Cashew apple	*Anacardium occidentale* L.	Anacardiaceae	*Saccharomyces cerevisiae*	[55]
Cherry	*Prunus cerasus* L.	Rosaceae	*Saccharomyces cerevisiae*	[56]
Cupuassu	*Theobroma grandiflorum* L.	Malvaceae	*Saccharomyces cerevisiae* UFLA CA 1162	[53]
Custard apple	*Annona squamosa* L.	Annonaceae	*Saccharomyces cerevisiae* NCIM 3282	[57]
Gabiroba	*Campomanesia pubescens* Berg.	Myrtaceae	*Saccharomyces cerevisiae* UFLA CA 1162	[53]
Guava	*Psidium guajava* L.	Myrtaceae	*Saccharomyces cerevisiae* NCIM 3905 & 3287	[58]
Jackfruit	*Artocarpus heterophyllus* L.	Moraceae	-	[53,59]
Jaboticaba	*Myrciaria jaboticaba* Berg.	Myrtaceae	*Saccharomyces cerevisiae* UFLA CA 1162	[53]
Jamun	*Syzygium cumini* L.	Myrtaceae	*Saccharomyces cerevisiae*	[4]
Kiwi	*Actinidia deliciosa* L.	Actinidiaceae	-	[60]
Litchi	*Litchi chinensis* L.)		*Saccharomyces cerevisiae*	[61]
Lychee	*Litchi chinensis* Sonn.	Sapindaceae	*Saccharomyces cerevisiae* UFLA CA 11, UFLA CA 1174 and UFLA CA 1183.	[62]
Mango	*Mangifera indica* L.	Anacardiaceae	*Saccharomyces cerevisiae* CFTRI 101	[63]
Marula	*Sclerocarya birrea* subsp. *Caffra*	Anacardiaceae	*Saccharomyces cerevisiae*	[64]
Melon	*Cucumis melo* L.	Cucurbitaceae	-	[65]
Orange	*Citrus sinensis* L.	Rutaceae	-	[66]
Palm	*Elaeis guineensis* Jacq.	Arecaceae	-	[67]
Papaya	*Carica papaya* L.	Cariaceae	*Williopsis saturnus* var. *Mrakii* NCYC	[68]
Peach	*Prunus persica* L.	Rosaceae	*Saccharomyces cerevisiae*	[69]
Pineapple	*Ananus comosus* L.	Bromeliaceae	Dried Bakery Yeast	[70]
Pomegranate	*Punica granatum* L.	Punicaceae	*Saccharomyces cerevisiae* var. *bayanus*	[71]
Sapota	*Achras sapota* Linn	Sapotaceae	*Saccharomyces cerevisiae*	[43]
Sweet Potato	*Ipomoea batatas* L.	Convolvulaceae	*Saccharomyces cerevisiae*	[72]
Tendu	*Diospyros melanoxylon* L.	Ebenaceae	*Saccharomyces cerevisiae*	[73]

Singh *et al*. [80] prepared a wine from kinnow juice with moderate acceptability as compared with grape wine. Other tropical fruits from which wine preparation are reported included carambola [81], papaya [82], mango [1], Black Mulberry [83], melon [65], marula [64], custard apple [79]. Mohanty *et al*. [84] prepared wine from cashew apple using *Saccharomyces cerevisiae* var. *bayanus* as the starter culture.

Many tropical fruits such as mango, jackfruit, banana, bael and cashew apple have been shown to be suitable for fermentation, mainly because of their appropriate taste, flavor, availability, high sugar and water contents and overall chemical composition [84]. Must from tendu fruits were made by raising total soluble solids (TSS) to 20°B, 0.1 % (NH_4) SO_4 as nitrogen source and fermenting it using 2 % *Saccharomyces cerevisiae* var *ellipsoideus* into wine. The wine had the following proximate compositions: TSS, 2 °B; total sugar of 3.78 g100 ml^{-1}; titratable acidity, 1.32 g tartaric acid 100 ml^{-1}; pH, 3.12; total phenolics, 0.95 g100 ml^{-1}; β-carotene, 8 μg 100 ml^{-1}; ascorbic acid, 1.52 mg 100 ml^{-1}; lactic acid, 0.39 mg 100 ml^{-1}, methanol, 3.5 % (v/v) and ethanol,6.8 % (v/v). The antioxidant contents of tendu wine were measured in form of 2, 2-diphenyl-1 - picrylhydrazyl (DPPH) scavenging activity of 52 % at a dose of 250 μg ml^{-1}. A wine, from jackfruit pulp, was prepared by fermenting with wine yeast as starter culture. The wine had the following proximate compositions: total soluble solids, 1.8° Brix; total sugar, 4.32 g.100 ml^{-1}; titratable acidity, 1.16 g tartaric acid. 100 ml^{-1}; pH, 3.52; total phenolics, 0.78 g.100 ml^{-1}; β-carotene, 12 μg.100 ml^{-1}; ascorbic acid, 1.78 g.100 ml^{-1}; lactic acid, 0.64 mg.100 ml^{-1} and ethanol content of 8.23% (v/v). The jackfruit wine had a DPPH scavenging activity of 32 % at a dose of 250 μg. ml^{-1}. The jackfruit wine was well accepted among consumers as per its organoleptic properties [74]. A red wine from jamun fruits was prepared with high anthocyanin content (68 mg 100 ml $wine^{-1}$) [4]. Similarly, wine prepared from sapota was rich in anti-oxidants (total phenolics, 0.21 g.100 ml^{-1}; β-carotene, 22 μg.100 ml^{-1}; ascorbic acid, 1.78. 100ml $^{-1}$) [43]. Wine, from β-carotene rich tropical bael fruits, widely known for their immense medicinal properties (anti-diarrheic, antibacterial and antiinflammatory) was prepared by fermenting with the wine yeast (*Saccharomyces cerevisiae*) as starter culture. The wine was rich in anti-oxidants like phenolics (0.93 g 100 ml^{-1}), β-carotene (33 mg 100 ml^{-1}) and ascorbic acid (80 mg100 ml^{-1}) [43]. In this context, many process characteristics have to be taken into account: adequate juice extraction and variables that may influence the final beverage quality such as must amelioration, enzyme application, vessel capacity, yeast strain involved and finally the storage method [85].

Health Benefits of Tropical Fruit Wines: In recent years, the demand for nutraceutical products which contribute to good human health, has led major food companies develop alternative products containing functional substances. Wine is one of the functional fermented foods having many health benefits like anti-ageing effects, improvement of lung function (from antioxidants in white wine), reduction in coronary heart disease, development of healthier blood vessels and reduction in ulcer-causing bacteria. Many wines are made from fruits having medicinal value [86].

Wine has enormous health benefits similar to those of fruits from which they are derived [87]. Almonds have been found to be more effective in reducing blood levels of low density lipoprotein cholesterol (LDLC) when combined with other foods known to independently lower cholesterol [88]. The consumption of citrus fruits like orange and lemon singly and especially when combined offer significant protection against various cancers, diabetes, Parkinson's disease and inflammatory bowel disease [89].

The chemical composition of wine is essential in order to establish a potential relationship and understanding its role with different beneficial biological activities enhancing human health benefits. Fruits containing a wide range of flavonoids and other phenolic compounds possess antioxidant activity. Phenolic compounds in red grape wine have been shown to inhibit *in vitro* oxidation of human low - density lipoprotein (LDL). The phenols and flavonoids compounds present in wines are known for their positive effects on inflammation, cardiovascular diseases, besides having antibacterial and antioxidant activities. The effort is to highlight some of the reported antioxidant activities of other fruit wines. Some of the reported values of DPPH activity and phenolic composition of various tropical fruit wines are discussed here [85].

The wine produced from the tropical fruits is the rich source for flavonoids. The flavonoids are the most abundant polyphenols which contain two or more aromatic rings connected to at least one aromatic hydroxyl group and a bridge of carbon. Of late these compounds have been the subject of many studies since these are identified with health benefits, ranging from prevention of caries to cancer. Much has been said about the functionality of these compounds that have anti-carcinogenic, antiatherogenic, antithrombotic, antimicrobial and analgesic vessel dilator effects [90, 91]. Some studies regarding the functionality of these compounds relate to their presence in green tea, fruits, vegetables and wines which possess large amounts of flavonols, antioxidant substances that fight free radicals [92].

Although, colorless or slightly yellowish, the flavonoids have an important role in strengthening and stabilizing the color of red wines. They contribute to the sensory characteristics such as taste, astringency and harshness of wine, in addition, to the preservation of the beverages and retaining properties of the wine aging process. Most phenols are in the form of tannins (molecules which preserve the wine by absorbing oxygen) or as flavonoid derivatives such as flavan-3-ols and flavan-3, 4- diols which can polymerize tannins. The most important representatives of the group of flavan-3-ols are the catechin and epicatechin, epimers at carbon 3 [93]. According to Teissedre *et al*. [94], among the various phenolic compounds present in wines, the greatest antioxidant activity in preventing LDL oxidation was impacted by flavan-3-ols such as catechin, epicatechin, dimmers and trimers of procyanidins, which characterize for highest antioxidant activity [94].

The epicatechin has not only a direct antioxidant effect but also is able to conserve other antioxidants such as vitamins C and E. Catechins and procyanidins have characterized to be potent inhibitors of LDL oxidation than α-tocopherol. Among the factors that explain this fact is the ease of flavonoids in capturing free radicals in the blood. When lipid peroxidation begins or occurs, the flavonoids may prevent the reaction by limiting the initial phase [95].

Due to the great diversity of metabolic processes in the formation of flavanol substances and of their similar chemical characteristics, it is difficult to estimate their quantitative content in plant tissues in an absolute manner. However, HPLC technique can provide different retention times to allow the identification of these compounds [96]. Typically, each species is associated with a particular family of polyphenols, the contents of which increase with age and vary with the vegetative development of fruit. Catechins and epicatechins are mainly present in grape seeds and are the main phenolic compounds responsible for flavor and astringency of wine and grape juice; however, some studies have revealed the presence of these flavanols in other vegetable matrices [97, 98]. The Brazil and in particular the North and Northeast regions are recognized as producers of exotic tropical fruits, whose high perishability requires the development of technologies for new products and thus reduce post-harvest losses. Studies show that fermented fruit drinks have been highlighted as better means of using these fruits, not only by having attractive sensory characteristics in products, but also because they are natural sources of phenolic compounds, substances which possess anti-inflammatory, antimicrobial and anticarcinogenic activities [92, 99].

Monagas *et al*. [91] reported that the catechin content in wines could increase on storage until 12 months. However, the flavonols content depends not only on the storage period, but it also gets effected by season, variety, environmental and climatic conditions, plant disease, geographic locations and even maturity in the matrix seems to play an important role in the concentration of phenolic compounds present in fermented beverages. This could as well explain the difference in the data on these compounds in cashew apple wines as the commercial wine prepared from cashew apple fruits had lower levels of catechin (3.99 mg L^{-1}) when compared with the cashew apple wine prepared in the laboratory (7.46 mg L^{-1} and 1.30 mg L^{-1} of catechin and epicatechin, respectively). Besides, high levels of catechin and epicatechin found in homemade wines may be related to the handmade process and hence the absence of substances used by industrial wineries such as polyvinyl polypyrrolidone what acts on the catechin and epicatechin, inhibiting them.

In young red grape wines, the concentrations of catechin and epicatechin were found to vary from 4.96 - 7.14 mg L^{-1} and 2.02 - 3.02 mg L^{-1} which were very similar to the data found in tropical fruits wines in this study with the exception of mangaba wine, which contained higher values (14.01 mg L^{-1} and 22.66 mg L^{-1} of catechin and epicatechin, respectively) [100]. Marquez *et al*. [101] reported comparable levels of catechin (6.8 mg L^{-1}) and epicatechin (1.5 mg L^{-1}) in red grape's wines, but, according to Gurbuz *et al*. [96] in the wines samples, the catechin was found to be the highest in red Bogazkere wine (14.357 mg L^{-1}).

In white wines where there is a limited contact with the skins, the catechins are the main flavonoids. These compounds are responsible for the browning of white or red wines and result also in some bitterness. This happens because flavanols are involved in enzymatic browning reactions and their interaction with proteins results in the turbidity of the beverages [95]. In wine making, the catechins are transferred to the must in the soaking step. However, during the manufacture of white wine, there is a quick press operation to separate peel and pulp which explains the fact that the low amount of phenolic compounds are present in white wines.

According to Auger *et al*. [102], small amounts, such as 1 mM of epicatechin are good enough for vitamins C and E, to be protected from oxidation. Moreover, the catechins present in plants and fruits are the main therapeutic, free radical scavengers, metal chelators, inhibitors to DNA damage by ROS (Reactive Oxygen Species) in skin inflammation and immune suppression induced by UV rays.

The Jack fruit wine showed high radical scavenging capacity of 69 % compared to that of wines prepared from lime (20.1±1.09 %), tamarind (15.7±0.63 %), garcinia (15.4±0.21 %), rambutan (15.1±0.26 %), star gooseberry (14.8±0.46 %) fruits, cashew apple 7.72 %, mango 42 %, bael wine 48 %, pineapple 36 % and tendu 52 %. Among the reported values Litchi has the highest DPPH activity of 86.7 due to high amount of phenolic content. On the other hand, a comparative study was taken for the grape wine and cashew apple wine for parameters such as total suspended solids, reducing sugar and phenol concentration and found out to be somewhat similar in both case. As expected, the grape wine has the highest antioxidant activity than all other fruit wines with the reported value of DPPH Activity (93-95 %) [103].

Several studies have revealed that the majority of the antioxidant activity of the fruit may be from compounds such as flavonoids, isoflavones, flavones, anthocyanins, catechins and other phenolics. Polyphenols act as free radical-scavengers quenching hydroxyl radicals (OH) or superoxide anion radicals (O.2). Further, the lower pH of the wine is highly favourable for the stability of the polyphenols as they are known to autooxidize with increase in pH. It was reported that jack fruit wine contains total phenolics as 0.053 mg GAE ml^{-1}, the result indicated that jack fruit wine has lower levels of phenols and flavonoids as compared to red wine which contains high phenolic content averaging 2567 mg GAE L^{-1}. Moderately alcoholic bael wine has a phenolic content varying slightly between the must and the wine samples (1.02 g100 ml^{-1} in must; 0.93 g 100 ml^{-1} in wine). Total phenol content of the bael wine (0.93 g 100 ml^{-1}) was higher than that of cashew wine (0.12 g 100 ml^{-1}), litchi wine (0.22 g 100 ml^{-1}) and jamun wine (0.22 g100 ml^{-1}). Tendu wine, with the phenolic content of 0.95g/100 ml is much higher than the commercial grape wines and other tropical fruit wines [2].

Custard apple popularly known as sugar apple or custard apple (in Tropical and Sub-tropical countries) or sweetsop, is a species native to tropical America and is cultivated in different tropical areas around the world. Custard apple wine showed free radical scavenging activity towards DPPH, DMPD and FRAP. The reverse phase high pressure liquid chromatography with diode array detector analysis showed a presence of three hydroxyl benzoic acids (gallic acid, protocatechuic acid, gentisic acid) and two hydroxyl cinnamic acids (caffeic acid and p-coumaric acid). Additionally, Custard apple fruit wine was also able to protect γ-radiation (100 Gy) induced DNA damage in pBR 322 plasmid DNA suggested that it may has potential health applications and therefore could contribute to the economy of the wine industry [57].

Jamun fruits also possess some medicinal properties and used for curing diabetes because of their effects on the pancreas [104]. Anthocyanin rich Jamun fruits were fermented with *Saccharomyces cerevisiae*, which resulted in a sparkling red wine having an acidic taste, high tannin content and low alcohol (6 %) concentration. Jamun wine also possessed medicinal properties like antidiabetic properties and the ability to cure bleeding piles [4]. The sensory analysis accepted jamun wine as an alcoholic beverage. However, it was significantly differed from the commercial grape wine particularly in taste, flavor and after taste lingering effects probably due to the high tannin content in the Jamun wine [4]. On the other hand, Nuengchamnong and Ingkaninan [105] used HPLC coupled on-line to a radical scavenging detection system and MS to identify and characterize antioxidant compounds in *Saccharomyces cumini* fruit wines. The major antioxidants found were a complicated mixture of hydrolysable tannins and fruit acids.

The evolution of volatile components during Litchi wine making and aroma profiles of litchi wines determined using HS-SPME-GC/MS showed that the majority of terpenoids derived from Litchi juice decreased, even disappeared during alcoholic fermentation, while terpenol oxides, ethers and acetates increased. However, ethyloctanote, isoamyl acetate, ethyl hexanoate, ethyl butanoate, cisrose oxide and transrose oxide had the highest OAVs in young Litchi wines offering floral and fruity attributes. Compared to ambient temperature with bottle aging, lower temperature benefited key aroma retention and (as expected) extended the shelf life of young Litchi wines [61].

Guava fruit is a good source of ascorbic acid, pectin, sugars and certain minerals with widely appreciated flavor and aroma. Guava juice was fermented with two different *Saccharomyces cerevisiae* NCIM 3095 and NCIM 3287 strains and optimization of guava wine fermentation with respect to osmotolerance, alcohol tolerance, inoculum size, initial pH of the medium, amount of SO_2, amount of di-ammonium phosphate and incubation temperature were studied. For guava wine production, *S. cerevisiae* NCIM 3095 gave much better results [106]. GC/FID and GC/MS analysis of guava wine revealed the presence of 124 volatile constituents including 52 esters, 24 alcohols, 11 ketones, seven acids, six aldehydes, six terpenes, four phenols and derivatives, four lactones, four sulphur compounds and five miscellaneous compounds. The odorant compounds (E)-β - damascenone, ethyl octanoate, ethyl 3-phenyl propanoate, ethyl hexanoate, 3-methyl butyl acetate, 2 –methyl tetrahy-drothiophen-3 - one, 4-methoxy - 2, 4-dimethyl-3 (2H) - furanone, ethyl (E) - cinnamate, ethyl butanoate, (E)-cinnamyl acetate, 3-phenyl propyl acetate and ethyl 2-methyl propanoate were considered as odour-active volatiles.

The fruit of the Actinidia plant is known more commonly as Kiwifruit. Soufleros *et al*. [107] investigated the chemical composition and evaluated sensory properties of Kiwifruit wine. Towantakavanit *et al*. [108] evaluated the fruit maturity value of ‘Hayward’ Kiwifruit as material for wine production. The pre-treatment of ripe Kiwifruit pulp with pectinase increased the yield of wine production from 63.35 % to 66.19 %. The wine produced from over - ripened fruits have soluble solid content (13.5 %) with a high amount of potassium as compared to the wine produced from ripe fruit (10.3 %). However, difference in fruit maturity did not affect acidity, pH, colour, total phenolic content and antioxidant activities of wine significantly. The Kiwifruit wine made from over-ripened fruits treated with pectinase was superior in many ways, such as sensory value, alcohol and total phenolic content, antioxidant activity, minerals and production yield [108].

Palm wine is the fermented sap of the tropical plants of the Palmae family. It is produced and consumed in very large quantities in the South - eastern Nigeria. It contains nutritionally important components including amino acids, protein, vitamins and sugars [109]. Palm wine is a traditional wine extracted from palm trees; *Elaeis guineenis* and *Raphia hookeri.* Although, palm wine may be presented in a variety of flavors, ranging from sweet (Unfermented) to sour (fermented), it is mostly enjoyed by people when sweet [110]. Most studies on palm wine have reported its potentials as source yeast isolate for the fermentation industries. Palm wine is a source of minerals especially potassium. The physico-chemical characteristics of a typical palm wine were analyzed as follows: pH (4.0), alcohol (12.86 %) and the minerals analyzed were: phosphorus, sodium, calcium, magnesium, iron, manganese, copper, zinc and potassium all in ppm. The protein content of the wine was about 0.61 %.

Mango contains a high concentration of sugar (16-18 % w/v) and many organic acids and also contains antioxidants like carotene (as Vitamin A, 4,800 IU). Sucrose, glucose and fructose are the main sugars in ripened mango. The unripe fruit contains citric acid, malic acid, oxalic acid, succinic acid and other organic acids. In contrast, in ripe fruits, the main organic acid is malic acid [111]. Mango wine along with aromatics is recommended as a restorative tonic; as it contains good amount of vitamin A and C which are useful in heat apoplexy. Mangoes with higher initial concentration of α-carotene are helpful as cancer-preventing agents.

Papayas are high in protein, fat, fiber and carbohydrates in comparison to other temperate fruits such as peaches. It is a rich source of vitamin A, potassium and carotenoids. Papaya has also been used for the production of papaya wine and alcohol content of the same has been reported to be 11.3 % [112].

The Jackfruit is a rich source of phenolics and flavonoids which in turn have good antioxidant properties found out that jackfruit pulp contains calcium 20 mg, phosphorus 30 mg, iron 500 mg, vitamin-A 540 I.U., thiamin30mgandcaloricvalue 84 calories per 100 g and prepared wine from jackfruit juice for the development of functional beverages with health beneficial properties comprising nutraceuticals and phytochemicals. Jagtap *et al*. [103] prepared wine from jackfruit pulp and evaluated the total phenolic content, flavonoid contents and antioxidant properties of wine. The jackfruit wine was effective in DPPH radical scavenging (69.4470.34 %), FRAP (0.358 optical density value, O.D.), DMPD (78.4570.05 %) and NO (62.4670.45 %) capacity. The two phenolic compounds namely gallic acid and protocatechuic acid were identified in jackfruit wine. The jackfruit wine was also able to protect H_2O_2 and UV radiation and γ-radiation (100 Gy) induced DNA damage in pBR322 plasmid DNA. The antioxidant and DNA damage protecting properties of Jackfruit wine confirmed health benefits when consumed in moderation and could become a valuable source of antioxidant rich nutraceuticals.

The edible Cashew apple is almost neglected in commercial terms, as compared to the nut. Cashew apple juice, for being rich in sugar with high mineral contents, is a very good raw material for alcoholic fermentation. The investigation of the alcoholic fermentation of cashew apple is an old concept. Evident from work of some Brazilian research institutes have been working together to develop a novel fermented beverage similar to wine. An enology procedure was established to obtain a type of dry white wine, called base wine formulated to produce sweet and sparkling wines, brandies and coolers. Cashew apple wine obtained is light yellow (in appearance) beverage with an alcohol content of 7.0 %. It was slightly acidic (1.21 g tartaric acid 100 ml^{-1}), which, together with comparatively high tannin content (1.9 ± 0.22 mg 100 ml^{-1}), imparted the characteristic cashew apple flavor and astringency. Lactic acid concentration in this wine was very low (2.5 mg 100 ml^{-1}) [113].

The consumption of Banana wine provides a rich source of vitamins and enhances harnessing of the fruit into useful by-product as banana is available all year round. Banana is a good source of sugars and fibers which make it a good source of energy. When consumed, it can reduce depression, anemia, blood pressure, stroke risk, heartburns, ulcers, stress, constipation and diarrhea. It confers protection for eyesight, healthy bones and kidney malfunctions, morning sickness, itching and swelling, improves nerve functions and is said to help people to quit smoking.

Purple sweet potato (PSP) is a rich source of anthocyanin pigments. A herbal PSP wine was prepared from purple fleshed sweet potato rich in anthocyanin pigment and 18 medicinal plant parts (fruits of ink nut, Indian gooseberry, garlic, cinnamon, leaves of holy basil, night jasmine, Malabar nut, roots of belladonna, asparagus, rhizome of ginger, etc.) by fermenting with wine yeast, *Saccharomyces cerevisiae*. The herbal

PSP - wine was a novel product with ethanol content of 8.61 % (v/v) and rich source of antioxidant anthocyanin which offers remedies for cold, coughs, skin diseases and dysentery [114].

Cacao is known worldwide for its beans, which are used in the production of chocolate and related products. The production and commercialization of cacao beans have long been the basis of the economy of some Brazilian states, especially Bahia. The pulp of the cacao fruit is a substrate rich in nutrients and is a by-product of the processing of the fruit and is a source for the production of wines and other products. The Cacao fruit pulp juice was fermented with yeast and analysis of minor and major compounds in cacao wine were carried out by using GC/MS and GC/FID [53]. The C6 compounds, alcohols, monoterpenic alcohols, monoterpenic oxides, ethyl esters, acetate esters, volatile phenols, acids, carbonyl compounds, sulphur compounds and sugars were identified in the analyzed wines. The results suggested that the use of Cacao fruits in the production of wine is an available alternative that allows the use of harvest surpluses and other under used Cacao fruits, introducing a new product into the market [115].

Orange is the most important Citrus fruits cultivated throughout the tropical and sub-tropical areas of world. A total of 64 volatiles, including higher alcohols, esters, terpenes, acids, volatile phenols, lactones, acetal compounds, ketone, aldehydes and acetoin were analyzed in blood Orange wine by GC/FID and GC/MS [116]. However, the juice and wine prepared from the cv. Kozan of Turkey contained higher amounts of citric acid and sucrose. Orange juice and wine were rich sources of phenolic compounds hydroxyl benzoic acids, hydroxyl cinnamic acids and flavanones along with hesperidin, narirutin and ferulic acid. The antioxidant capacity of orange juice was found to be higher than that of orange wine. However, 75 volatile components including terpenes, alcohols, esters, volatile phenols, acids, ketones, aldehydes, lactones and C13-norisoprenoids were identified in Kozan wine. Amongst these, Isoamyl alcohol, 2-phenyl ethanol, linalool, terpinene-4-ol and ethyl-4 –hydroxy butanoate were the main components contributing to the wine aroma along with ethyl hexanoate, ethyl octanoate, citronellol and eugenol [117].

The Pomegranate wines were rich in anthocyanins which was responsible for the antioxidant properties and colour of the wine. Therefore, Pomegranate wine provides a new value added product that offers beneficial health effects [71]. Similarly in another study, [71] reported the presence of melatonin (N-acetyl-5 - methoxytryptamine) in the wine made from pomegranate cultivars. Melatonin (N-acetyl-5 - methoxytryptamine) is a eurohormone related to a broad array of physiological functions and has proven therapeutic properties. Some foods also contain melatonin and their consumption has been considered as an exogenous source, able to increase melatonin circulating levels.

CONCLUSION

Fruits both in fresh as well as in processed form not only improve the quality of our diet but also provide essential ingredients like vitamins, minerals, carbohydrates etc. Fruit wines are undistilled alcoholic beverages usually made from grapes or other fruits such as peaches, plums or apricots, banana, jamun, jackfruits, mango, etc. 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 release of amino acids and other nutrients from yeast during fermentation. Wine is one of the functional fermented foods having many health benefits like anti-ageing effects, improvement of lung function (from antioxidants in white wine), reduction in coronary heart disease, development of healthier blood vessels and reduction in ulcer-causing bacteria. Many wines are made from fruits having medicinal value.

Most studies have been done on wine making potential of the tropical fruits and its radical scavenging activities. Tropical fruit wines as observed have fair amount of antioxidant potential and charming flavor. The variation in antioxidant potential is mainly due to various natural factors such as cultivation, vinification processes and maturation time in wood and in bottle ageing. Tropical fruit wines if consumed in low levels each day can certainly improve health as per the findings. Nonetheless, new process and technology are warranted to produce tropical fruit wines with novel flavors. While wine making is a promising way of over ripe and underutilized tropical fruit processing but to produce and create acceptability of tropical fruit wines of high quality, many researchers are concerned about appropriate parameters of fermentation and other factors of its source. This chapter attempts to cover a wide topic of increasing interest. It covers selected tropical fruit wines that have attracted limited attention so far due to smaller global market. In future, it can be changed with changing consumers' perception for high-quality nutritional content wine with diverse flavors, taste and appearance besides dominant commercial red wine which leads to a new horizon for further scope of study in tropical fruit wines leading to exploration of its potentials aiding human health.

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