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Fermentation of wine from tropical and subtropical fruits: A review

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Abstract
Fruit is an important part of your diet using crucial part of vitamin and minerals that contribute to overall strength for your health. Recent updates on wine production from various tropical and a subtropical fruit like mango, Grape, banana, jamun, jackfruit, pomegranate and apple cider is also reported. These fruits go through a period of fermentation and aging. They generally have an alcohol content ranging between 5 and 13%. Wines making from fruits are often named after the fruits. No other drinks, except water and milk, have earned such worldwide acceptance and esteem throughout the ages as has wine. Wine is a drink 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 generally most of the nutrients present in the original fruit juice. The nutritive value of wine is improved due to the release of amino acids and other nutrients from yeast during fermentation. Traditionally, the fruit juice was fermented by wild yeast. However, with the developments in the field of fermentation, different strains of *Saccharomyces cerevisiae* and various fruit juices have been used for wine production. Fruit wines normally contain 8–11% alcohol, 2–3% sugar and energy value ranges from 70 to 90 kcal per 100 ml. In this present review, we discussed about fermentation, history of fermentation, production, consumption, export and import, health benefits of wine, fermentation of wine from tropical and suptropical fruits and Indian wine market.

Keywords: Fermentation**,** fruit, wine, yeast, alcohol

Introduction
Fruits are the most important foods of mankind as they are not only nutritive but are also indispensable for the maintenance of health. Fruits both in fresh as well as in processed form not only improve the quality of our diet but also provide essential nutrients like vitamins, minerals, carbohydrates etc. Postharvest losses of fruit are one of the biggest problems of tropical countries like India. Due to improper postharvest practices and inadequate processing facilities almost 35 to 40 per cent of horticultural production goes waste. The wastage cost is estimated to be Rs 40,000/- crores each year (Vidhya, R. and Narain, A. 2011) [1]. The fruit and vegetable processing industry in India utilizes less than 2 per cent of the total production of fruits and vegetables for conversion in to, as adjacent to 40 to 50 per cent in highly developed countries.

Depending on the various attributes such as cultivar, stage of ripening in fruits, chemical composition of juice, uses of additives to the must, vinification techniques and ageing of wine vis-a-vis the alcohol and sugar content in wine. They are classified as natural wines (9-14% alcohol), dessert and appetizer wines (15-21% alcohol). Dry wine, sweet table wine, speciality wine, champagne, muscat and burgundy wines are natural wines while sweet wine, sherries, vermouth and port wines are regarded as dessert and appetizer wines (Amerine and Singleton., 1972) [2]. They are having nutritional components like ethyl alcohol, sugar, acids, higher alcohols, tannins, aldehydes, esters, amino acids, minerals, vitamins, anthocyanins, minor constituents like flavouring compounds etc (Amerine *et al*. 1980) [3].

The wine making science is called as enology. Fruit wines are undistilled alcoholic beverages which are nutritive, new tasty and mild stimulants (Darby, 1979) [4]. Wines made from fruits. No other drinks, except water and milk have earned such worldwide acceptance and esteem throughout the ages as has wine. Being fruit contained fermented and undistilled product, wine contains most of the nutrients present in the original fruit juice. The nutritive value of wine is increased mainly release of amino acids and other nutrients from yeast during

fermentation. Fruit wines alcohol content 8 to 11 per cent and 2 to 3 per cent sugar with energy value ranging from 70 to 90 Kcal per 100 ml. The ethanol content in the wine enhances the taste of the food.

An alcoholic beverage is a drink and it's mainly contains ethanol. These are divided into three common classes for taxation and regulation of production namely 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 corn, rye, wheat or blend of multi grains and generally flavoured with hops. It contains 4 to 8 per cent alcohol and its energy value ranges from 28 to 73 kcal per 100 ml. Distilled alcoholic beverages are processed by distilling ethanol by fermentation of grains, fruits or vegetables and normally they are prepared from sugarcane juice, molasses, fermented mash of cereals and potatoes and fermented malt of barley and rye. The alcohol content in distilled alcoholic beverage normally ranges between 40 and 60 per cent.

History of fermentation

In this world Fermentation is one of the oldest forms of food preservation technology. Indigenous fermented foods like bread, cheese, and wine have been made and consumed for thousands of years and are strongly related to culture and tradition, particularly in rural households and village communities. The advance development of fermentation technologies is lost in the midst of history. Anthropologists have postulated that it was the production of alcohol that encouraged primitive people to settle down and become agriculturists. Some level think that the consumption of fermented food is pre-human (Hornsey., 2012) [5].

The first fermented foods consumed probably are fermented fruits. Hunter-gatherers would have been consumed fresh fruits but in times of insufficiency would have eaten rotten and fermented fruits. Repetitive consumption would have led to the improvement of the taste for fermented fruits. There is a reliable matter that fermented drinks were being make produced over 7000 years ago in Babylon, 5000 years ago in Egypt, 4000 years ago in Mexico and 3500 years ago in Sudan (Yokotsuka., 2015) [6]. There is also confirmation of fermented meat 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 prepare 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 (Dirar., 1993) [7].

Knowledge about traditional fermentation technologies for the has been handed over from parent to child, for centuries. These fermented like wine and other have been adapted over generations; some and practices no doubt fell by the wayside. Those that remain today have not only survived the test of time but also more essentially are appropriate to the technical, social, and economic conditions of the area. According to (Robinson., 2016) [8], natural happening of fermentation means that it was probably first observed long ago by humans. The most primitive uses of the word "Fermentation" in narrate to wine making are in reference to the apparent "boiling" within the must that came from the anaerobic response of the yeast with sugars in the grape juice and liberate of CO_2. The Latin "fervere" literally means to boil. In the mid-19th century, Louis Pasteur noted the association between yeast and the process of the fermentation in which the yeast acts as medium 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 20th century contributed more to the thoughtful of the complex chemical processes implicated in the conversion of sugar to alcohol.

Indian wine market

Wine Production

Maharashtra, Karnataka and Himachal Pradesh are the three major wine producing regions in India. In these, Maharashtra is the highest producer and consumer of wine. After a decade of steady growth between 2000 to 2010, India's wine production declined from 13.0 million liters (ML) in 2010 to 11.0 ML in 2011. The wine production of Maharashtra and Karnataka is 14.2 ML (1.58 million cases) in 2014, as cooler temperatures during February and March enhanced grape yields and quality. The wine production was decrease in mainly due to growers switching to table grapes and other crops, consumers drinking habit were change, tourism were dropped, high land cost and state level ground ceiling, wine policies and rupee depreciation. Even with all these obstacles, the governments of Maharashtra and Karnataka have supported domestic wine industries by relax excise duties on local wines, easing delivery restrictions and provided that fiscal incentives to establish wineries and vineyards, and imposing excise taxes on imported and wines from other states (Sathish and Chandra., 2012) [9].

Wine Consumption

India ranks 77th position in the World wine consumption. The per capita consumption of wine in India is only 0.07 L/person/year. Indian country accounts for 0.8% of the total wine consumed in Asia. In India, 80% of wine consumption is cramped to major cities such as Mumbai (39%), Delhi (23%), Bengaluru (9%), and Goa (9%) (Jagtap., 2014) [10]. Major factors adding up to the increased wine consumption are growing population, higher non-refundable incomes, relaxation on government guideline and policies. According to the information of All India Wine Associations, Indian wine consumption is likely to rise at a CAGR of around 18% during 2014–2015. The forecast of Vinexpo survey stated that consumption of wine in India is expected to reach 2.1 million cases by 2017, an increase of 73% from 2013. Indians accounted for wine consumption 1.15 million cases of red wine, 0.63 million cases of white wine and 0.10 million cases of rose wine by 2017.

Wine Exports

Cabernet Sauvignon, Sauvignon Blanc, and Chenin Blanc are the export quality wines to enhance the importance of Indian wine in the global market. China, Singapore, Japan, Nepal, and Bhutan are the probable markets for Indian wines and are gaining greater acceptance in US and France also. At present, Wines are imported by Malaysia, UAE, Bhutan, Germany, UK, Sri Lanka, Maldives, and New Zealand for India. There was a modest rebound of 2.6 ML in Indian wine exports for the period of 2010 and had reached to 739,000 L (2100 cases) in 2012. In India exports of wine was accounted for about Rs. 80–100 crores and is expected to increased by Rs. 500 crores in the next 5 years (Thaliath and Kumar. 2014) [11].

Wine Imports

Current Indian reported trade data recommend that the top three wine suppliers to India are France, Australia, and Italy and wine imports from "New World" wine countries are growing, particularly for Australian, American, South

African, and New Zealand, while imports from France and Italy have fallen (Wimalsiri *et al*., 1971) [12]. Mumbai terror attacks and ban on imported wines, there was a huge drop in Indian wine imports. Imported wines are sales through hospitality (63%) and retail (30%) sectors are the two important marketing segments (Elijah *et al*. 2017) [13]. It was an increase, in wine imports since 2009 and reaching a range of 44,000 hL in 2011 and are on pace to match that level in 2012 (Esparza *et al*., 2013) [14]. Lower domestic production and persistent promotion efforts appear to be yielding results for imported wines (Saranraj *et al*., 2013) [15].

Health benefits of Fermented beverages:

Fruits are rich sources of phytochemicals, which are essential for human health and relished by consumers in all seasons. In all over the world there are hundreds of edible tropical fruits and some of fruits which have very high export potential. Most of the tropical fruits are important source of antioxidants, vitamins, dietary fibres and minerals and form a very healthy part of our diet (Reddy and Reddy, 2011) [16]. Fruit juices had a good medium for cultivating probiotics. Furthermore, fruits and vegetables do not contain any allergens, as in case of dairy, that might cause allergy in some certain segments of the population. 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 (Idise and Odum, 2011) [17].

Alcohol in the wine, stimulates gastric-secretions, depresses nervous system and offers relaxation. Polyphenols in the wine have been reduced the cholesterol level in blood. Wines are, increase high density lipoproteins (HDL) level which is also known as good cholesterol in the body. A chromium containing compound called as glucose tolerance factor (GTF) is used in diabetes. It presence of resveratrol prevents cancer (Marwaha and Arora,. 2002) [18]. Red wines can cure the risk of lung cancer. Moderate amount of drinking wine can increase bone mass in elderly women. Also, the people want to use wine for reduce anxiety, stimulate the appetite and improve digestion by increasing stomach acids (Sharma *et al*. 2013) [19].

Wine Making Technology

Wine making are mainly three categories of operations, *viz*: pre-fermentation, fermentation and post fermentation operations (Iland *et al*., 2000) [20] (Jackson (2000) [21] and (Ribéreau-Gayon *et al*. 2000) [22]. In case of wines produced from grapes, pre-fermentation involves crushing the fruit and releasing juice. In case of white wine, juice is separated from the skin, red wine the skins are not separated from the juice. Clarification of juice and white wine is usually achieved by sedimetation or centrifugation. Then yeast is mixed in 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 colour and flavour. Yeast was added to mashed pulp (must) for the preparation in red winemaking.

Fermentation involves a reaction that converts the sugars in to alcohol and CO_2. Yeasts use the sugars during the fermentation period. A wedged fermentation occurs when yeasts do not completely utilise the available sugar and the rate of fermentation slows down and/or ceases. Clarification was achieved by racking, filtration and/or centrifugation. Fermentation of wine proceeds under anaerobic conditions, and may be boosted with di-ammonium phosphate (DAP) to supplement nitrogen. It's required for yeast growth in non-traditional approach of winemaking. Post fermentation practices are done after fermentation of wine has reached the desired level or fermentation is complete. Wine is racked off the yeast less and normally kept in stainless steel vessels or in oak barrels. In storage period of wine, the wine may be filtered, cold stabilised, fined and/or blended.

Various clarifying and fining agents like enzymes, bentonite, diatomaceous earth, egg albumen etc. was commercially purchased and added to aid in clarification of wines. The wine was continued changes during maturation, filtered and bottled for storage.

Wines from tropical and subtropical fruits

Many tropical and subtropical fruits, including grapes, apples, pears, apricots, berries, peaches, cherries, oranges, mangoes, plums, karonda, pomegranate, guava, bananas and pineapples yield good amounts of juice on extraction. Upon fermentation of wine was performed by fruit juices can be changed into wines.

Mango wine

Mango, the pride fruit of India, is an important tropical fruit farm occupying about 60% of the total area under cultivation in India. Twenty-five different mango varieties are available in India, and appreciated for its light to bright yellow in colour. Its having sweet and delicious taste, high nutritive value (high amounts of amino acids, a good source of vitamin A and B6, and low in saturated fat, cholesterol, and sodium), as well as its affordable market price (Spreer *et al*. 2009) [23]. Mango juice along with aromatics is recommended as a restorative tonic; as it contains good amount of vitamin A and C and it's a useful in heat apoplexy. Mango fruits are having high content of β-carotene are helpful as cancer-preventing agents (Anon. 1962) [24]. (Gathambiri, 2009) [25] Reported a percentage post-harvest loss of 45% and the main reason cited was excess fruits in the market during the peak season. Production of wine from mango fruits was one of the alternative ways to use and convert surplus production into a valuable product and minimise the post-harvest losses (Reddy and Reddy, 2005) [26].

(Musyimi *et al*. 2013) [27] prepared wine from Apple mango variety with varying temperature (20°C, 25°C, 30°C and 35°C) and the yeast concentration (0.0065%, 0.01%, 0.05% and 0.1%). Yeast (*Saccharomyces cerevisae*) concentration at 0.05% and temperature of 25°C gave the optimal characteristics for Apple mango wine.

(Reddy and Reddy, 2009) [28] investigated on the fermentation conditions (like yeast strains, pectinase enzyme, *p*H and temperature), production of higher alcohols and other volatile compounds during wine fermentation from mango fruits (Banganapalli, Alphonso' and 'Totapuri'). The *Saccharomyces cerevisiae* CFTRI 101 produced most acceptable wine with higher alcohol content (150 - 300 mg L^{-1}) compared to the other two strains such as baker's yeast (123 -200 mg L^{-1}) and (PWY1) palm wine isolate (100 - 185 mg L^{-1}). Good taste and favour components were observed in wine produced from 'Banganapalli' variety (343 mg L^{-1}) than wine from 'Totapuri' variety (320 mg L^{-1}).

(Reddy and Reddy, 2011) [29] Investigated on effect of fermentation conditions [temperature (15 - 35ºC), pH (3.5 - 6.0), SO_2 (100 - 300 ppm) and aeration (initial dissolved O_2 and shaking at 30 rpm)] on mango fruit wine fermentation based on yeast growth, duration, fermentation rate and

volatile composition. The study revealed that the temperature had significant effect on yeast growth and on the ranges of volatile compounds. Optimum processing parameters were the temperature (25 ºC), pH (5), SO_2 (100 ppm) in must with initial oxygen for good quality of wine production from mango fruits.

Table 1: The fruits, variety, starter culture and strains used for the fermentation of fruit wine.

Fruits & Varieties	Starter culture & Strain	Reference
Grape (Chenin blanc Black cornichon)	*Schizo saccharomyces pombe & Saccharomyces cerevisiae*	Suresh negi, 1975 & Ethiraj and Suresh, 1978 [30, 31].
Grape (Chholtu Red, Chholtu White, Rang Spray, Thompson Seedless & Anab-e-Shahi	*Saccharomyces cerevisiae*	Sharma *et al.*, 1997 [34].
Grape (Chenin blanc)	*Saccharomyces cerevisiae*	Beer *et al.* 2005 [63].
	Saccharomyces cerevisiae	Patil *et al*. 2007 [64].
	Saccharomyces cerevisiae	Kallithraka *et al*. 2009 [65].
Apple (Golden Delicious and Red Delicious)	*Saccharomyces cerevisiae*	Vyas and Kochhar, 1993 [66].
Mango (Fazri, Langra and Chausa Dashehari)	*Saccharomyces cerevisiae*	Kulkarni *et al.*, 1980 [67].
Mango (Totapuri, Nekkare, and Mallika)	*Saccharomyces cerevisiae*	Thippesha 1994 [69].
Pomegranate (Ganesha)	*Saccharomyces cerevisiae*	Kumbhar *et al.*, 2002 [69].
Pomegranate (Ganesha & Bhagwa)	*Saccharomyces cerevisiae* NCIM-3095	Nikrad 1993 [70].
Pomegranate (Ganesha & bhagwa)	S. cerevisiae var. ellipsoideus NCIM NO 3215 and C. stellate NCIM NO 3433	Charushila *et al*., 2014 [71].
Jamun (Kath Jamun and Pharendra)	*Saccharomyces cerevisiae*	Shukla *et al.*, 1991 [72].
Jamun	*Saccharomyces cerevisiae* var. ellipsoideus strain SC3287	Sonar *et al*., 2004 [73].
Jamun	*Saccharomyces cerevisiae*	Taskar 2007 [74].
Jamun	*Saccharomyces cerevisiae*	Jagtap 2010 [75].
Jamun (Black jamun)	*Saccharomyces cerevisiae*	Joshi *et al*. 2012 [76].
Banana	*Saccharomyces cerevisiae*	Jackson and Badrie, 2003. [78]Kotecha *et al.*, 1994 [77, 78]
Banana	*Saccharomyces cerevisiae*	Shanmugasundaram *et al.* 2005 [79].
Banana	*Saccharomyces cerevisiae* NCIM 3594	Tagad *et al*. 2011 [39].
Pineapple	*Saccharomyces cerevisiae*	Roodagi 2010 [80].
Cashew apple	*Saccharomyces cerevisiae*	Fernandes 2010 [81].
Cashew apple (Bayanus)	*Saccharomyces cerevisiae*	Mohanty *et al*. 2006 [82].
Guava	*Saccharomyces cerevisiae* NCIM 3095 and NCIM 3287	Sevda and Rodrigues 2011 [60].
Guava	*saccharomyces cerevisiae* 3090, 3095,3287	Jawahar *et al.*, 2001[83].
Guava	*Saccharomyces cerevisiae*	Diwan and Shukla 2004 [84].
Guava	*Saccharomyces cerevisiae*	Kocher and Pooja 2011 [85].
Papaya (C02)	*Saccharomyces cerevisiae*	Maragatham and Panneerselvam, 2011 [61].
Jack fruit (Vellipala)	*Saccharomyces cerevisiae*	Sharma *et al*., 2013 [19].
Jack fruit	*Saccharomyces cerevisiae*	Kumoro *et al*. 2012 [51].
Fruit extracts (tomato, almond, orange, lemon and African star apple)	*Saccharomyces cerevisiae*	Agbor *et al.* 2011 [58].
Sapota (Kalipatti and cricket ball)	*Saccharomyces cerevisiae*	Pawar 2009 [49].
Sapota (Kalipatti)	*Saccharomyces cerevisiae*	Vijaykumar, A. B. 2012 [50].
Sapota (Kalipatti)	*Saccharomyces cerevisiae* NCIM-3095	Honde and Adsule 1998 [86].
Karonda	*Saccharomyces cerevisiae*	More 2010 [87].
Star gooseberry	*Saccharomyces cerevisiae*	Sibounnavong *et al*. 2010 [56].
Strawberry (Sujatha)	*Saccharomyces cerevisiae*	Saravana Kumar *et al*., 2001 [54].
Ber	*Saccharomyces cerevisiae*	Marimuthu, and Thirumaron, 2002 [88].
Carrot	*Saccharomyces cerevisiae* var. ellipsoideus strain No. 522	Lingappa and Naik, 2002 [52].
Orange	*Saccharomyces cerevisiae*	Rodriguez *et al*., 1991 [89].
Muskmelon	*Saccharomyces cerevisiae*	Teotia *et al.*, 1991 [90].
Apricot	*Saccharomyces cerevisiae*	Joshi *et al.*, 1990 [91].
Carambola	*Saccharomyces cerevisiae*	Lakshmana *et al.* 2006 [92].
Litchi	*saccharomyces cerevisiae MTCC178*	Singh and kaur 2009 [93].
Dried *ficus*	*Saccharomyces cerevisiae* NCIM 3282	Kadam *et al*. 2011 [59].
Tendu	*Saccharomyces cerevisiae*	Sahu *et al*. 2012 [94].
Star fruit	*Saccharomyces cerevisiae*	Adhiyaman, P. 2014 [62].

Grapewine

Suresh and Negi, (1975) [30] reported that among thirty grape varieties Chenin Blanc and Black Cornichon is known as good quality dry table wines. The relative acidity content of wine in eight varieties of grape fermented with *Schizo saccharomyces pombe* was found to be low when compared with *Saccharomyces cerevisiae* (Ethiraj and Suresh, 1978) [31]. Among different cultivars of grape, Early Muscat, Pearl of Csaba, Champion, Mandeline Augevine, Bianshi Rai, Riesling and Jaosbeli, good quality dry white table wine was

obtained from champion, pearl of Csaba and Early Muscat (Kundu *et al*.1980) [32]. Four grape cultivars namely Arkavati, Arka Kanchan, Arka Shyam and Arka Hans were suitable for good quality dry wine production and the first three cultivars also have good quality sweet wine (Suresh *et al*. 1985) [33]. Wines prepared from Chholtu Red, Chholtu White, Rang Spray, Thompson Seedless and Anab-e-Shahi cultivar of grape of third harvest were of good quality and wine from Thompson Seedless had highest fermentation rate and alcohol content (Sharma *et al*. 1997) [34].

Banana wine

Banana is a tropical fruit belonging to the family Musaceae and genus *Musa* spp. which is grown abundantly in India. Banana is the fourth most important crop after rice, wheat and maize and international trade in bananas is valued at around US$5 billion per annum (Sunday Monitor, 2007) [35]. Bananas have high content of nutrition sources like carbohydrates, minerals especially potassium and vitamins such as B_1, B_2, B_3, B_{12}, C and E. It can be dried and processed into flour, chips, and dried fruit (Gopinath, 1995) [36]. Cooking bananas are crushed into porridges and used for beer production. The fibre is used for making ropes, sacks and mats. The banana peel is made into sheets of paper and paper board (Obaedo and Ikenebomeh, 2009) [37]. For preparation of banana wine the bananas are cooked, juice is extracted, added with wine yeast, citric acid, sugar and maize flour mixed well and left for 2 days in a pot. Then it is put into a jerry can with an airlock for 14-30 days followed by filtration with a filter siphon into another can. It is kept for some time before consuming.

(Sevda *et al*. 2010) [38] reported wine from ripe banana using pectinase enzyme and two strains of *Saccharomyces cerevisiae* NCIM 3283 and NCIM 3046 with acceptable qualities in terms of flavor, taste, clarity and overall characteristics. (Tagad *et al*. 2011) [39] reported banana wine by using *Saccharomyces cerevisiae* NCIM 3594 using 50 per cent banana pulp and water (v/v). The total soluble solids (TSS) and pH of banana pulp was adjusted to 24° brix and 3.8 to 4.2 by the addition of powder sugar and citric acid. Sensory evaluation revealed that the banana wine had 10 to 14 per cent alcohol content with excellent sensory attributes such as clarity, colour (golden yellow), aroma, taste and overall acceptability.

Apple cider and wine

Apple (*Malus domestica*) fruit is used to prepare mild alcoholic beverages which are more nutritious than distilled liquors (Joshi and Thakur, 1994) [40]. The apple fruit is more associated with cider than any other alcoholic beverages (Joshi, 1995) [41] and (Sandhu and Joshi 1994) [42]. Cider is a low alcoholic drink produced by fermentation of apple juice and is believed to have been produced for over 2000 years. Cider is known by different names around the world such as *cidre* (France), *sidre* (Italy), *sidra* (Spain) and *apfel wein* (Germany and Switzerland). Cider can be sweet or dry. Depending upon the alcohol content, cider is categorised into soft cider (1-5%) or hard cider (6-7%) (Downing, 1989) [43]. Sparkling ciders contains low sugar levels and CO_2, usually sweet cider and still cider contain no CO_2, while dry cider contains little sugar and an alcohol content of about 6-7% (Joshi, 2000) [44]. Simultaneous fermentation of apple juice with *Saccharomyces cerevisiae* and *Schizosaccharomyces pombe* produced a cider with acceptable level of alcohol and acidity (O'Reilly and Scott, 1993) [45].

Mostly stainless steel tanks are used these days for fermentation of cider (Downing, 1989) [43] though traditionally barrels of oak were used for this purpose. A temperature of 40°C is suitable for bulk storage of ciders. After fermentation, the cider is racked and filtered. During aging, most of the suspended material settles down leaving the rest of the liquid clear which may be clarified with bentonite, casein or gelatin followed by filtration. After aging and clarification ciders needs to be pasteurized at 60°C for about 20-30 minutes or SO_2 can be used. Apple wine is another product made from apple juice by alcoholic fermentation and has alcohol content ranges from 11 - 14%. Like cider, apple juice or concentrate is the basic raw material, but as the alcohol content of wine is more than that of cider, amelioration with sugar or juice concentrate is essential (Joshi *et al*. 2000) [44].

Pomegranate wine

The preliminary studies for producing wine from pomegranate showed that a good quality wine can be successfully prepared from pomegranate juice. The rate of fermentation of pomegranate juice was, however, slower than that of grape juice. The sensory evaluation studies showed that pomegranate wine had better flavour and colour than the grape wine (Adsule, *et al*., 1992) [46]. An investigation was undertaken to find out effect of stage of fruit maturity on quality of wine from the juice of Ganesh cultivar of pomegranate. Pomegranate juice extracted by hand press method, was good for pomegranate wine making (Kumbhar *et al*.2002) [47]. Inoculum levels (5%) and pH (4.0) of the must the optimum conditions for preparation of pomegranate wine (Nikrad, 1993) [48].

Sapota wine

(Pawar, 2009) [49] studied on standardization of wine making technology in sapota [*Manilkaraachras* (Mill) Forsberg]. The juice extracted from different stages of sapota (half ripe, ripe and over ripe) was used for the production of standard quality sapota wine. The study result indicated that the sapota wine prepared from juice of ripe fruit was the best compared to half ripe and over ripe fruits. The 0.1 per cent pectinase treatment and 1:1 dilution of sapota juice was found to increase quality of sapota wine. The blending of sapota juice with local mango and alphonso mango juice in 1:0.5, 1:1, 1:1.5 and 1:2 proportions could not improve the quality of sapota wine. The prepared wine quality was slightly increased during aging at 13 to 15^{0}C for six months.

(Vijaykumar, 2012) [50] Studied that juice was extracted from ripe sapota fruits. From this juice, must was prepared by adjusting different levels of T.S.S. [control (T_1), 25 (T_2), 30 (T_3) and 35(T_4) ^{0}B] and pH [3.0(P_1), 3.5 (P_2) and 4.0(P_3)] and analyzed for chemical composition. Among these interactions T_3P_2 (T.S.S. 30 ^{0}B and pH 3.5) was found to be the best as it recorded highest overall quality (average score) score for sensory quality, followed by T_3P_1 (T.S.S. 30 ^{0}B and pH 3.0).

Jackfruit wine

(Kumoro *et al*. 2012) [51] investigated the effects of baker's yeast (*Saccharomyces cerevisiae*) and initial sugar concentrations on wine production from jackfruit juice. Clarified jackfruit juice (14% TSS) was fermented using 0.5 to 2.0 per cent (w/v) baker's yeast (*Saccharomyces cerevisiae*) under anaerobic condition at 30°C for 14 days. The ethanol and sugar contents were analyzed daily from the collected samples. The results of the study showed that the

initial sugar concentration (14% TSS) and higher yeast inoculums rate inhibited growth of yeast cell.

(Sharma *et al*. 2013) [19] developed wine from jackfruit (*Artocarpus heterophyllus* Lam.*)* using yeast (*Saccharomyces cerevisiae*). The developed jackfruit wine contained 18 per cent of alcohol with high polyphenols (7.5% mg L^{-1}) and antioxidant activity (36%). Jackfruit wine had sweet aroma and excellent sensory characteristics. The study indicated that the wine processing is a promising method for the value addition of jackfruit.

Other fruit wines

Fermentation studies were conducted to find out suitability of carrots for wine preparation with native yeast strain and *Saccharomyces cerevisiae* var. Ellipsoides No. 522. The wines produced by both strains were compared for their chemical and sensory qualities. The results revealed that carrots can serve as good substrate for preparation of good quality wine (Lingappa and Naik, 1998) [52].

The Karonda fruits of different ripening stages were chemically analyzed and used for wine making. The over ripe Karonda fruits produced a beautiful, tasty cherry red coloured wine with 8.26% alcohol and 438 ml/kg wine yield. The wine prepared were rated as standard wines and compared well with grape wine. A maximum yield of 770 ml wine could be obtained from 1 kg Karonda fruit (Bhajipale, 1998) [53].

Wine was prepared from two varieties of strawberry fruits namely Sujatha and Labella. The strawberry wines were organoleptically evaluated before and after ageing (90 days) and the wine from Sujatha variety has acceptable (Saravanakumar, 2001) [54]. (Chowdhury and Ray, 2007) [55] reported that prepared red wine from anthocyanin-rich tropical jamun fruit by fermentation using wine yeast (*Saccharomyces cerevisiae*) and the quality attributes were compared with commercial grape red wines. The result of the study revealed that the red wine prepared from jamun fruit was sparkling red in colour, acidic in taste [titratable acidity (1.11 ± 0.07 g tartaric acid. 100 ml L^{-1})], high tannin (1.7 ± 0.15 mg. 100 ml L^{-1}) and low alcohol (6%) concentration.

(Sibounnavong, *et al*. 2010) [56] studied wine from star gooseberry by application of *Saccharomyces cerevisiae* for two weeks. The results indicated that the yeast (*Saccharomyces cerevisiae*) plays an important role in consumption of nutrients as starch and sugar with the release of ethyl alcohol. The star gooseberry wine was found to contain 15.90 per cent ethyl alcohol after fermentation of two weeks. Research carried out (Ogunjobi, and Ogunwolu, 2010) [57] on the development and physicochemical evaluation of wine produced from cashew apple powder. The must prepared by mixing 75 g of cashew apple powder with 1 litre of distilled water and then ameliorated to 20° brix. The inoculum of baker's yeast (*Saccharomyces cerevisiae*) was used for fermentation at the concentration level of 1 g L^{-1}. The result of the study revealed that the wine produced from cashew apple powder was light brown, slightly acidic in taste, low tannin content (0.60 mg $100ml^{-1}$), high vitamin C content (14.2 mg $100ml^{-1}$) and low in alcohol content (7.2%).

(Agbor, 2011) [58] reported on the production and characterization of wine from a blend of five fruit extracts (tomato, almond, orange, lemon and African star apple) and also determined the safety of the wine on seventy male and female albino wistar rats. Results of the investigation identified glycosides, reducing compounds, polyphenols and tannins in the multi-fruit wine but not in the standard wines. The animal study results indicated that the high dose of multi-fruit wine produced higher liver superoxide dismutase (SOD) activity compared to control, which means that the multi-fruit wine did not produce free radicals. It has reported that the wine is safe for human consumption and had better health benefits than commercial red wine. (Kadam *et al*. 2011) [59] studied the fermentation and characterization of wine from dried *Ficus carica* L. using *Saccharomyces cerevisiae* NCIM 3282. The result of the study revealed that the wine had 76.45 per cent of radical scavenging activity (RSA), which indicated that the wine had significant amount of antioxidant properties and low alcohol contain (4.5%).

The fermentative behavior of Saccharomyces strains (*Saccharomyces cerevisiae* NCIM 3095 and NCIM 3287) during guava (*Psidium guajava* L.) must fermentation and optimization of guava wine production was studied by (Sevda and Rodrigues, 2011) [60]. The study optimized fermentation parameters of *Saccharomyces cerevisiae* NCIM 3287 such as fermentation temperature (25°C), pH (4), diammonium phosphate (0.06%) sulphur dioxide (100 ppm) and 6% inoculum level for production of better quality of guava wine with good hue and flavour.

Papaya wine was developed from clarified, non-clarified papaya juice and papaya pulp separately. Cane sugar was used to adjust the final TSS to 24° brix. The inoculums pure culture of wine yeast (*Saccharomyces cerevisiae*) was used for fermentation at the concentration level of 5 ml / kg pulp / juice. The result of the study revealed that the wine prepared from either the clarified or non clarified papaya juice was highly acceptable in the terms of colour, taste aroma and sweetness with significant alcohol (10 to 11%) content (Maragatham and Panneerselvam,2011) [61].

(Adiyaman, 2014) [62] Stated that Star fruit juice and pulp were used for the development of wine. The juice was collected in fermentation flasks and the total soluble solids (TSS) of the juice were adjusted to 24° brix by addition of sugar and jaggery. The pH was adjusted to 3.5 by addition of citric acid / potassium hydroxide and treated with 50 ppm of potassium metabisulphite (KMS). Similarly the star fruit wine were also observed with decreasing trend of nutrients and bioactive compounds with advances in storage period. During aging, the decreasing nutrients and bioactive compounds were less in star fruit wine prepared using jaggery compared to star fruit wine prepared using sugar.

Conclusion

Today, wines can be made from any fruit other than grape, and the present review is a compilation of studies on wine preparation from fruits. While wine retail is catching up with the Indian consumer, the per capita consumption still needs to increase. Research reports surveyed, in this review, demonstrated that wine could be prepared from underutilized tropical and subtropical fruits, thereby helping efforts to increase shelf life by reducing post-harvest and production losses and the existing wine industry. Indian government has identified wine as a booming sector and has extended support in terms of subsidizing processing facilities and reducing VAT. By analyzing the alcohol consumption of the Indian consumer, it can be said that traditionally consumers were more inclined towards spirits and beer, while wine has been steadily gaining acceptance. This tendency can also be attributed to availability and affordability and lack of proper retail channels. India has witnessed a huge increase in wineries supporting the production and distribution mechanism; there is now a clear-cut need for world class wine retail infrastructure.

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