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Review Paper

Production of Wine from Mango Fruit: A Review

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Abstract

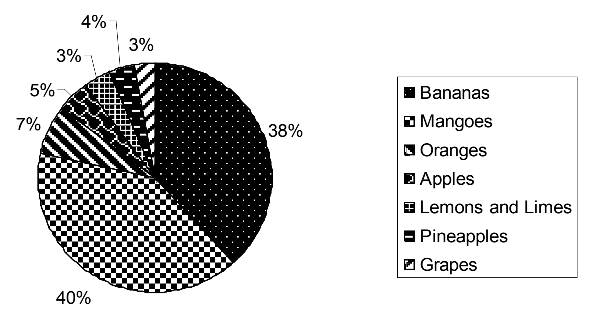
India is the largest producer of fruits in the world with an annual production of 46 million tons, However, accounting to 10% of the world production 20-30% of production get spoiled and remain unutilized as post-harvest losses and mango is no exception. Mango (*Mangifera indica* L.) is the most popular and the choicest fruit of India. Wine production from mango is a very good alternative to utilize the surplus and value addition. The literature available on mango wine production and characterization, the need of fruit wine and mango wine production and optimization of conditions has been reviewed briefly. The characterization of mango wine in terms of primary metabolite, ethanol and secondary metabolites like glycerol, volatile flavour compounds and phenolic compounds and antioxidant potentiality have also been covered. Cell immobilization in mango wine production, stabilization, other varieties of fermentation products like vermouth and economics has been focussed. To utilize the surplus for wine production, has potential to contribute considerably to postharvest loss reduction and providing value added products..

Keywords: Mango, wine production, optimization of fermentation conditions, volatile compounds, antioxidant activity.

Production and consumption of fermented beverages like wine is an ancient practice. However, production and consumption of fruit based distilled alcoholic beverages is a later development. Different aspects of fruit based alcoholic beverage other than grapes have been investigated (Barnett, 1980). Rigveda amply testifies that the wine is perhaps the oldest fermented product known to man. However, still the actual birthplace of wine is unknown though it had been prepared somewhere in 350 BC (Robinson, 1994; Joshi and Attri, 2005). European explorers in the 16th century introduced the wine into the new world (Amerine *et al.*, 1980). Wine has been made in India for as many as 5,000 years. In most of the world's wine regions, at least until around the middle of the 1980s, wine has been made by fermentation with the indigenous yeasts present on the grapes when harvested, or introduced from the equipment and cellar during the vinification process. Recently, in order to ensure that must fermentation is rapid and complete and can produce wines of reproducible character and quality, the practice of adding selected yeasts to slightly sulphited musts has become widespread. Presently, the majority of commercial wine yeasts are strains of *Saccharomyces cerevisiae*, including those described by enologists as *S. bayanus*, which has been re-identified in most cases as *S. cerevisiae*.

Fruits are highly perishable commodities and have to be either consumed immediately or preserved in one or the other form. In the developed countries, a considerable quantity of fruit is utilized, but in developing countries, lack of proper utilization results in considerable postharvest losses, estimated to be 30-40%. The increased production can be soaked profitably, if fruit wines are produced (Sandhu and Joshi 1995). Setting - up of fruit wineries besides industrialization of the fruit growing belts could result in economic upliftment of the people, generating employment opportunities and providing better returns of their produce to the orchardists (Amerin *et al*., 1980; Fowles 1989; Joshi *et al*., 2004). Availability of technology is the single important factor determining the production though cost and type of the product is also a significant consideration in popularising the product. So production of fruit wines in those countries where fruits other than grape are grown would certainly be advantageous.

The world's total annual mango fruit production was estimated at 35 million tonnes. Global production of mangoes is concentrated mainly in Asia and more precisely in India that produced 12 million tonnes per annum. Mangoes are cultivated in 85 countries. Asia and the oriental countries produced around 80% of the world's total production. Major mango producing countries are India, China, Thailand and Pakistan. The crop is significantly important in the fruit economy of India and is the 3rd largest industry in the country. In India mango is grown in 2 million acres and it occupied 40% of total fruit production (Figure 1). It is the most cultivated area occupied crop in India with 60% of the total area under fruits. More than 25 types of mango cultivars are available in India that is widely cultivated all over the world (Anon 1962). In Andhra Pradesh mango occupying an area of 3.7 lakh hectares, with an annual production of 44.07 lakh tonnes, has placed the state in first position with a share of 24% of the India's production coupling with highest productivity (APEDA 2014). Mangoes are highly perishable tropical fruit, with a shelf life of 2-4 weeks at 10-15°C (Yahia 1998), limiting their availability in fresh markets. An alternative and profitable method of using mangoes for winemaking could become widely acceptable. Many investigators have carried out much research on mango composition, and on cultivation aspects and this review will give the detailed upto date knowledge on mango wine research.



Source: APEDA 2014

Fig. 1: Production of different fruits in India (2004)

Why wine production from mango pulp

The ever-increasing fruit production calls for development of preserving and processing technologies. In India, efforts have been made to utilize the surplus (after export) and small and unattractive mangoes for various purposes; one of the alternatives is wine production. Fruits are utilized to produce a variety of alcoholic beverages including different types of fruit wines and their distillates are known as brandy. These beverages have been a part of food of man ever since his settlement in Tigris Euphrates basins and were used as therapeutic agents. While fruit wines are produced and consumed throughout world, hard liquors still constitute the big chunk of alcoholic beverages consumed in India.

A review of research on wine production done in India revealed that an impressive progress has been made in the development of technologies for preparation of wines of different types from various fruits. Successful marketing of grapes and apple wines in India is an indicator of potential Indian market waiting for fruit wines (Joshi and Pandey 1999; Joshi and Parmar 2004).

Screening of mango varieties

Suitability of mango cultivars for wine production is generally carried out based on juice quality, quantity and the physico-chemical characteristics. Screening of commercially available mango cultivars for winemaking has been reported by Czyhrinciwk (1966); Kulkarni *et al.*, (1980); Onkarayya and Singh (1984) and Obisanya *et al.*, (1987). According to their reports, the composition of wine is changed with mango variety used in the fermentation and screening and selection of good mango variety is essential. Kulkarni *et al.*, (1980) screened 13 cultivars available in north India for their suitability for wine making and suggested that wine made from varieties *Fazri*, *Langra* and *Chausa* were good. Reddy and Reddy (2005) screened 10 mango cultivars and among the ten varieties they used, six varieties showed promising juice yields (450-550ml/1kg mango). In mango, three types of sugars are present viz., glucose, fructose and sucrose. The totals soluble solids (TSS) of the mango juice are in the range of 14.2 to 20.5%. *Banginapalli* (20.5%) variety had high TSS and titrable acidity as tartaric acid ranged from 0.310 to 0.462% (w/v). The pH of the juices is in the range of 3.8 to 4.5 (Table 1). It was suggested that the concentration of ethanol, organic acids, tannins and aromatic volatiles compounds produced were different with mango variety (Table 3). Recently, Li *et al.*, (2012) studied the quality of mango juices of three varieties, R2E2, Harum Manis and found that Nam Doc Mai as the best variety.

Screening of yeast strain

Inoculation of must with selected yeasts minimize the influence of wild yeast on wine quality though the contribution of wild yeasts to the synthesis of volatile compounds during inoculated fermentations is not known. In mango wine fermentation, different investigators used different yeast strains. Fifteen morphologically different groups of yeasts were isolated from fresh, fermenting and fermented juice of two varieties of mango (Suresh *et al.*, 1981). Onkarayya and Singh (1984) used the *S. cerevisiae* strain and Reddy (2005) have screened the three types of

Table 1. Physico-chemical characteristics of mango pulp

Mango variety	Juice yield (ml/Kg)	Reducing sugars (% w/v)	Titrable acidity (%)	pH	TSS* (%)
Alphonso	570± 10	16.3±1.32	0.33	4.1±0.53	16.0±1.2
Raspuri	600 ± 13	15.5±2.21	0.43	3.9±0.86	14.2±1.8
Banginapalli	550 ± 17	18.5±1.24	0.32	4.0±0.6	20.5±0.79
Totapuri	500 ± 22	16.0±1.0	0.31	4.2±1.0	16.5±1.2
A. Banesha	500 ± 15	18.0±0.8	0.32	4.5±0.45	20.1±1.42
Neelam	480 ± 20	15.5±1.7	0.42	4.3±0.8	15.5±1.5
Mulgoa	468 ± 8	14.3±1.4	0.42	4.3±0.5	15.0±1.24
Suvarnarekha	470 ± 12	15.0±0.55	0.40	3.9±1.3	14.4±0.58
Rumani	475 ± 14	14.5±1.0	0.39	4.2±0.72	14.6 ±1.43
Jahangir	460 ± 10	15.6±1.62	0.46	4.6±0.56	14.2±1.3

(*Source*: Reddy and Reddy, 2009)

yeast strains that were isolated from different sources. To evaluate the fermentation performance, the yeast strains are subjected to different temperature and pH during fermentation. From the three yeast strains, *Saccharomyces cerevisiae* CFTRI 101 showed promising results at all the conditions followed by the yeast strain isolated from palm wine and the yeast strain that was purified from commercial baker's yeast. (PWY1). The baker's yeast could not ferment or utilize the complete sugar from the mango must, and the fermentation rate is also slow. The palm wine yeast strain's fermentation rate was comparable to that of CFTRI 101, but it could not tolerate high concentrations of ethanol, which is the most desirable character for wine fermentation. Recently, Li *et al*., (2012) conducted a study to compare the chemical and volatile composition of mango wines fermented with *Saccharomyces cerevisiae* var. *bayanus* EC1118, *S. cerevisiae* var. *chevalieri* CICC1028 and *S. cerevisiae* var. *cerevisiae* MERIT.ferm. Strains EC1118 and MERIT.ferm showed similar growth patterns but strain CICC1028 grew slightly slowly. Mixed culture technology was also used to improve the wine quality (Li *et al*., 2012 Sudheer *et al*., 2011). Impact of williopsis yeast strains was studied by Li *et al*., (2012). They found that the retaining of most terpenoids derived from mango juice unlike mango wine fermented with *Saccharomyces cerevisiae*, suggesting the mango wine could retain the aromatic hints of fresh mango.

Optimization of mango wine production conditions

Reddy and Reddy (2005) have studied the preliminary process for the production of wine from mango. Kumar *et al*., (2009) optimized the fermentation conditions, temperature, pH and inoculum size using Response Surface Methodology (RSM). Reddy and Reddy (2010) have been investigated the effect of fermentation conditions like temperature, pH, SO_2 and aeration on mango wine composition and yeast growth.

Enzyme Treatment

Pectolytic enzymes have been used in fruit juice processing for several purposes like extraction, clarification, liquefaction and maceration (Rombouts and Pilnik 1978; Pilnik and de Vos 1983; Sreenath *et al*., 1987, 1995). Since the mango pulp contains high quantity pectin and thus, needs pectinase treatment for the clarification of juice. A decrease of 50% or more of the relative viscosity of mango pulp resulted from different times of maceration with pectolyase and with 3 of the 4 commercial enzyme preparations (Sakho *et al*., 1998). Preliminary studies have been carried out by Reddy (2005) and Reddy and Reddy (2009a) to optimize the conditions for maximum extraction of juice, using different levels of pectinase enzyme and different incubation periods at 28$\pm$ °C. Based on these studies, 0.6% pectinase and 8h of incubation time were selected for obtaining the juice from the pulp. The juice was separated by centrifugation and the clear juice was used for the preparation of wine by slight modification of the method described. Pectinase treatment increased the juice yield and fermentability of mango pulp. In addition to this, pectinase treatment increases the fermentation performance, as well as chemical component production, during wine fermentation. The total higher alcohol content was higher in pectinase treated wines in comparison with control wines. Recently studies were conducted to evaluate the influence of pulp maceration and β-glucosidase on mango wine physico-chemical properties and volatile profile *et al.,* 2013. It was observed that the wine with pulp contact contained about ten times higher α-terpinolene and up to three times higher acetate esters than the wine without pulp contact, but mitigated the production of medium-chain fatty acids and relative ethyl higher quantity of ethyl esters up to six times. β-glucosidase enhanced terpenols by up to ten times and acetate esters by up to three times. Furthermore, enzyme treatment mitigated, by up to five times, the formation of medium-chain fatty acids and ethyl esters to moderate levels. Sensory evaluation showed pulp contact, and β-glucosidase not only improved the intensity and complexity of wine aroma but balanced odour attributes (Li *et al*., 2013). Finally, it is suggested that the pectinase and other carbohydrate hydrolytic enzyme treatment is useful and essential to produce more quality wines from the fruits fruits like mango.

Temperature

Temperature have the positive influence on fermentation- to some extent, temperature increases the yeast growth, speed of enzyme action (approximately doubles with every 10 °C rise), cell sensitivity to the toxic effect of alcohol increases with temperature due to increased membrane fluidity. This may partially explain the rapid decline in yeast viability at temperatures above 20°C during wine fermentation (Torija *et al*., 2002). Reddy and Reddy (2010) reported that the starting of fermentation, reaching of maximal cell population and decline of yeast population at 15°C and 20°C are slow compared to fermentations at 25°C, 30°C and 35°C. It was observed that the fermentations at 30°C was completed in short time and consumed all the available sugars. Further increase in temperature (at 35°C) delayed the fermentation and left residual sugars. High yeast mortality might have caused a slower fermentation rate in the final stages of the fermentation at 35°C. In contrast, low temperature fermentations, which started more slowly, consumed faster all the sugars because the high biomass was maintained throughout the process. The sum of all the secondary metabolism products increased as fermentation temperature increased from 15°C to 35°C. Temperature affects not only the fermentation kinetics (rate and length of fermentation) but also the yeast metabolism, which determine the chemical composition and the quality of wine. Several authors observed the increased glycerol levels than the control at high temperature (Totija 2002; Cardi 2003; Kourkoutas *et al*., 2003a; Reddy and Reddy 2009b and 2010). Increase in temperature increased the volatile composition and also yeast biomass. At higher temperatures more glycerol is produced. The enhanced production of glycerol at warm temperatures counters the bitterness of tannins, and generates a smoother mouth-feel. The fermentation at low temperatures such as <15°C leads to more aromatic and paler wines. Based on the published work it can thus be suggested that the fermentation temperature has great influence on the wine quality and yeast growth compared to all other tested variables.

pH

Optimum pH value is necessary for yeast growth and ethanol production. Most of the yeasts grow very well between pH 4.5-6.5 and nearly all species are not able to grow in more acidic or alkaline media. Low or high pH values are known to cause chemical stress on yeast cell. The enzyme aldehyde dehydrogenase activity is increased at high pH values and acetic acid is produced. This oxidation generates a molecule of NADH, which requires re-oxidation to maintain the redox balance of the cell (Walker, 1998). It is also confirmed that the optimum pH is very important to produce good quality wines. Response surface methodology was also used in optimization of fermentation conditions. According to Kumar *et al.,* (2009) the optimum pH for mango wine fermentation was 3.8.

Sulphur dioxide (SO_2)

Sulfur dioxide plays an important role in wine production as it is an anti-microbial agent, and as such is used to help curtail the growth of undesirable fault producing yeasts and bacteria and it acts as an antioxidant, safeguarding the wine's fruit integrity and protecting it against browning. Addition of SO_2 does not cause any delay on the onset of the alcoholic fermentation except in higher concentrations (200 mg/l). At normal dose (100 mg/l, which generally used in commercial wine fermentations) slight stimulatory effect was observed in the initial stages of fermentation (first 2 to 3 days). Alcoholic fermentation in both cases completes in 7 days. Apart from slight enhancement in ethanol production, SO_2 also caused some effects on volatile compound synthesis during fermentation. It slight increased the acetaldehyde concentration, the effect was dose dependent (at 100 ppm it produced 30 mg/l as compared to 25 mg/l at without SO_2) (Reddy and Reddy, 2011). However, SO_2 has little effect on wine quality. But high concentrations can decrease the yeast growth. It has been suggested that SO_2 can stimulate the fermentation by *Saccharomyces* in wine by inhibiting the polyphenol oxidase. On the basis of the results obtained, it could be confirmed that the addition of SO_2 induces acetaldehyde formation by yeast in mango wine fermentation. Similar results have been observed in production of grape wine and cider making (Herraiz *et al*., 1989; Herrero *et al*., 2003).

Oxygen (O_2)

When correctly applied, oxygen interacts with both the yeast and the wine/must in such a way that yeast health is improved, fermentations encounter less problems, and the resultant wine quality is often more approachable with fresher aromas and tastes than it had been previously observed (Seha 2006). Reddy and Reddy (2011) have reported that the aeration can improve the cell growth and initial fermentation rate. The fermentation was completed faster (5 days) with aeration and it took longer time in the absence of oxygen. The viability of yeast cells was increase (8×10^6 cells/ml) with aeration than in absence of oxygen (5×10^6 cells/ml). Oxygen appears to be involved in the synthesis of oleic acid and ergosterol, which stimulates yeast growth under anaerobic conditions. Presence of dissolved O_2 increases both the ethanol and yeast biomass. Finally, it can be conclude that optimization of fermentation conditions are very crucial in obtaining best quality wine from mango juice.

Characterization of mango wine

Mango wine has been characterized in terms of ethanol and glycerol concentration, higher alcohols, carotenoids, ployphenols and volatiles present (Reddy *et al*., 2009; Kumar *et al*., 2009; Varakumar *et al.,* 2010 and Li *et al*., 2010).

Ethanol and Glycerol

The principal metabolite produced during wine fermentation is ethanol. From the fermentation of mango juice, ethanol was produced in higher concentration than other metabolites. In general, the concentration of ethanol contributes to the whole characteristic quality and flavour of the produced wine. The percentage of ethanol produced in the mango wines was between 7-8.5% (w/v), when no sugar is added and is comparable with moderate grape wines (Table 2). Glycerol concentration in mango wines is between 5.7-6.9 g/L. Acids Another parameter, which highly influences the quality of wine, is its acidity. The main organic acid present in mango musts and produced wine was malic acid; and the other acids were less than 1 g/L.

Higher Alcohols and other Flavour Compounds

Mango fruit is known to have good aroma and flavour. wherein is because of the volatile components that are present (Pino and Queris 2010) and import such aroma to the wine also. The flavour of mango wine depends on many factors, fermentation conditions, varietal or fermentative compounds, which are present in highly variable amounts, and are mainly alcohols, esters,

Table 2. Physicochemical characteristics of mango wine produced at 22 ± 2oC and pH 5

Mango variety	Ethanol (%w/v)	T.A* (%v/v)	V.A* (%v/v)	pH	Residual Sugars (g/l)	Higher alcohols (mg/l)	Total esters (mg/l)	Tannins % (w/v)	Colour OD at 590nm
Alphonso	7.5	0.650	0.100	3.8	2.1	300	25	0.011	0.22
Raspuri	7	0.735	0.210	3.8	2.4	200	29	0.072	0.18
Banginapalli	8.5	0.600	0.181	3.7	2.0	343	35	0.012	0.23
Totapuri	7	0.622	0.121	4.0	2.0	230	20	0.012	0.17
A. Banesha	8	0.610	0.110	4.0	2.0	320	30	0.013	0.25
Neelam	6.5	0.826	0.234	3.6	2.5	131	15	0.014	0.21
Mulgoa	6.3	0.621	0.109	3.9	3.0	152	18	0.065	0.28
Suvarnarekha	6.8	0.630	0.153	4.1	2.3	175	22	0.025	0.19
Rumani	6.9	0.618	0.125	4.0	2.1	212	15	0.027	0.24
Jahangir	7.1	0.646	0.138	3.8	2.0	256	21	0.042	0.16

(Source: Reddy and Reddy 2009)

Table 3: Composition of volatiles forms three different mango varieties (*Banginapalli, Alphnso and Totapuri*) fermented at 25±2oC and pH 4.5 for 10 days.

S.No	Retention Time (RT)	Name of the compound	*Banginapalli* (mg/l)	*Alphanso* (mg/l)	*Totapuri* (mg/l)
Alcohols					
1	1.271	Ethanol%	8.5	7.5	7
2	1.350	Ethyl ether	solvent	solvent	solvent
3	1.492	1-propanol	54.11	42.32	47.13
4	1.729	Isobutyl alcohol	102.40	115.14	98.87
5	2.581	Isoamylalcohol	125.2	108.40	140.44
6	2.850	Pentane- 2 one	1.43	1.15	1.51
7	4.823	2-furan methanol	0.123	nd	0.216
8	6.535	Hexane-1-ol	1.42	1.02	nd
9	12.900	Phenethyl alcohol	22.15	24.15	20.48
10	19.414	Cyclohexane methanol	1.13	nd	1.34
11	42.58	n-pentanedecanol	0.610	nd	tr
Esters					
12	1.665	Ethyl aetate	35.15	30.42	27.48
13	6.876	Ethyl hexanoate	0.942	0.671	0.552
14	15.92	Ethyl octanoate	1.150	1.06	1.451
15	20.124	Ethyl decanoate	2.34	1.86	1.43
16	33.62	B-phenylethyl butanoate	nd	0.62	0.92
17	19.67	Dimethyl styrene	1.11	1.34	1.09
Acids					
18	1.950	Acetic acid	0.201	0.163	0.155
19	3.292	Propanoic acid	0.145	0.217	0.184
20	3.829	Butanoic acid	0.932	0.745	0.874
21	12.655	2-furoic acid	0.910	0.548	0.745
22	15.482	Benzoic acid	1.08	1.21	1.43
23	15.750	Phenyl formic acid	0.643	0.912	0.434
24	16,723	Octanoic acid	0.735	0.427	nd
25	37.99	Decanoic acid	1.18	0.963	tr
Ketones					
26	2.850	Pentane- 2 one	1.43	1.15	1.51
27	6.245	Furanone	1.12	1.51	1.22
28	11.489	Hydroxy-dimethylfuranone	0.238	0.452	0.331
29	25.967	Phenol 2,6-bis-4- methoxy- one	0.451	0.432	0.312
Unknown					
30	15.165		0.183	0.412	0.243
32	23.377		0.531	0.256	0.231
33	35.68		0.441	0.131	nd
34	38.86		0.12	tr	tr
35	46.34		tr	tr	Nd

terpenes, sulphur compounds, acids and lactones (Reddy *et al*., 2009; *Li et al*., 2010). Volatile aroma compounds are present in fruit juices and many are synthesized by wine yeast during fermentation. Reddy *et al*., (2009) screened many varieties for wine production and it was found that the three varieties, *Banginapalli, Alphanso* and *Totapuri* cv of mangoes are well suitable. The three major compounds (alcohols, esters and organic acids) are present in different concentration (Table 3). Recently, Pino and Queris 2010) reported the presence of 102 volatile compounds using advanced headspace solid-phase micro-extraction-gas chromatography-mass spectroscopy (HSME-GC-MS). According to their investigation, mango wine accounted for about 9 mg/l of volatile compounds, which included 40 esters, 15 alcohols, 12 terpenes, 8 acids, 6 aldehydes and ketones, 4 lactones, 2 phenols, 2 furans, and 13 miscellaneous compounds. Isopentanol and 2-phenylethanol were the major constituents. *Li et al*., (2010) investigated the aroma compounds present in fresh 'Chok Anon' cultivar mango juice and wine fermented with three different yeast strains.

Polyphenols, Carotenoid composition and Antioxidant activity

Abundant in antioxidants, mangoes are among the many fruits consumed for their potential health benefits including anticancer and antiviral activities and reduced risk of cardiac diseases associated with antioxidant activities (AOX) of polyphenolic and carotenoid compound (Shieber *et al*., 2000); *β*-carotene is the most abundant carotenoid in several cultivars. Phenolic compounds are considered basic components of wines and over 200 compounds have been identified in grape wine. Two primary classes of phenolics that occur in grapes and wine are flavonoids and nonflavonoids. The most common flavonoids in white and red wines are flavonols, catechins (flavan-3-ols), and anthocyanidins, the latter being found only in red wine. Wine polyphenols contribute to the wine colour and to other sensorial characteristics of wines such as bitterness and astringency (Perez-Magarino and Gonzalez-San Jose 2004). The concentration of total polyphenols varies with variety of mango fruit employed in wine fermentation. *Totaputi* mango variety contains highest concentration, 1050 mg/l followed by *Alphanso Banginapalli* and *Sindhoora* (725 mg/l 610 mg/l and 490 mg/l, respectively). Eleven different phenolic compounds were identified in the detailed analysis of *Alphanso* phenolic compounds using LC-MS. The antiradical activity range from 27.57 to 36.70% ascorbic acid equivalents, the antioxidant activity from 73.90 to 85.95% gallic acid equivalents and the reducing power varied from 0.71 to 2.90 6m/l ascorbic acid equivalents. The quenching of DPPH was formed to be dose dependents (Reddy 2005; Varakumar *et al*., 2010 and Kumar *et al*., 2010).

Carotenoids are responsible for the bright yellow color of mango and are important lipophilic radical scavengers found in many fruits and vegetables. Three carotenoids are synthesized in mango fruit and their concentrations increase toward ripening (Godoy and Rodriguez-Amaya 1989; Vazquez-Caicedo *et al*. 2005). The total carotenoids in the mango wines are in the range of 578-4330 μg/100g and the highest amount of total carotenoids from mango wine were in Alphonso 4330 μg/100g, followed by Sindhura 4101 μg/100g, Banginapalli 2943 μg/100g, Rumani 2857 μg/100g, Totapuri 690 μg/100g, Raspuri 634 μg/100g, and Neelam 578 μg/100g (Varakumar *et al*., 2010). In the mango wine xanthophylls (oxygenated carotenoids) were degraded more than β-carotene (hydrocarbon carotenoid). Among xanthophylls, lutein was degraded more ranging from 78.7 to 93.9%, followed by neoxanthin (26.8-83.3%) and violaxanthin (50-74.3%) (Varakumar *et al*., 2010).

Effect of storage Bottle colour and temperature on wine colour

Browning of bottled wines during storage has been reported by several researchers (Fabios *et al*., 2000; Selli *et al*., 2002 and Benitez 2003). Alaka *et al*., (2003) have reported the effect of bottle colour and storage conditions on mango juice chemical attributes. According to them, glass bottles will give greater protection against degradation of the chemical attributes of the mango juices. Packaging of Ogbomoso mango juices in glass bottles and storing them at 6^{o}C has provided protection against quality degradation. Reddy (2005) have been examined the change in the colour of the mango wine at 8, 16 and 25°C stored in white, green and brown coloured bottles based on the browning index. Wine which was stored in darker brown bottles at low temperature showed low browning indices that stored in white bottle. The contents of ascorbic acid and sugars together with storage temperatures, sunlight and colour of bottles affect browning in orange juice and orange wines [6±12]. Sunlight can cause undesired changes in wines. Therefore, in winemaking the use of bottles which will prevent transmission of short-wave lights such as ultraviolet, violet and blue is recommended, because short-wave lights have high energy and can initiate some chemical reactions (Boulton *et al*., 1996). In the brewery industry, brown bottles are commonly used to prevent transmission of lights with a wavelength between 350 and 550 nm, and formation of undesired aroma compounds (Moll 1999).

Table 4. Sensorial evaluation of ten mango wines produced from ten different mango varieties

S.No	Wine variety	Flavour	Taste	Texture	Appearance	Mouth feel	Overall acceptability
1	Alphonso	8.90	8.26	8.59^{b}	8.23^{ac}	8.85^{cd}	8.62^{cd}
2	Raspuri	7.22^{bc}	7.68^{ac}	8.14^{ac}	7.97^{bc}	8^{ac}	7.94^{ac}
3	Banginapal	8.56^{ac}	8.35^{bd}	8.45^{bd}	8.76^{cd}	8.5^{cd}	8.3^{bd}
4	Totapuri	7.84^{ac}	7.45^{ac}	7.98^{ac}	8.1^{ac}	7.6^{ac}	7.4^{ac}
5	Sindhoora	6.9^{ab}	6.4b	7.2^{ab}	8.45^{bd}	7.3^{bc}	7.2^{ad}
6	Neelam	6.5^{b}	6.65^{ab}	6.9^{b}	6.3^{a}	6.7^{b}	6.6^{b}
7	Rumani	7.1^{bc}	6.8^{bc}	7.3^{bc}	7.5^{ab}	6.6^{a}	7.0^{ab}
8	Himami pasand	6.1^{c}	6^{a}	6.3^{a}	6.7^{b}	6.9^{ab}	6.2^{a}

Values are given as mean ± Sd; Values not sharing a common superscript letter significantly at $P<0.05$ (DMRT)
(Source Reddy 2005 Reddy *et al*., 2009)

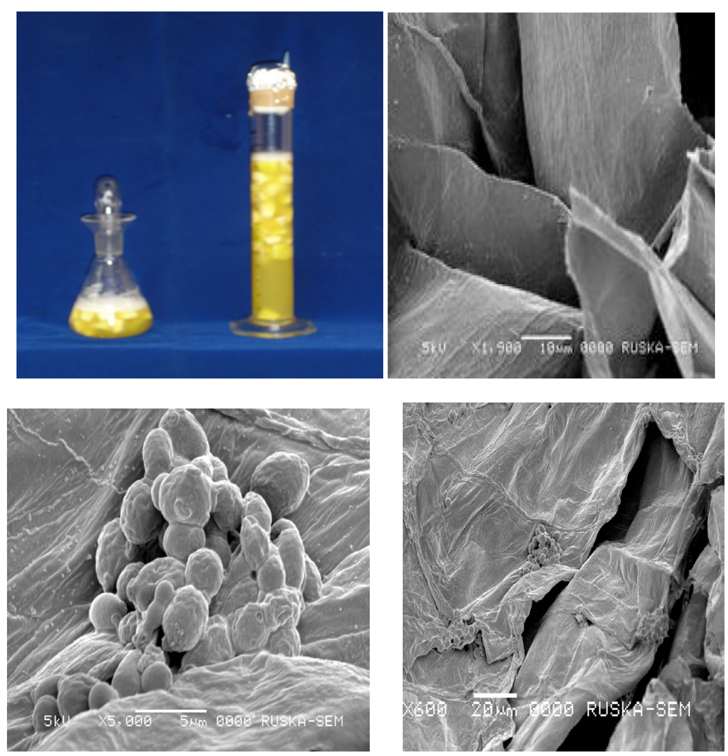


Fig. 2. Immobilization of yeast cells on watermelon pieces in mango wine fermentation and the yeast under the SEM.

Sensorial evaluation of mango wine

The mango wine quality is tested based on main characteristics visual, aroma, taste and harmony. From the Table 4 it can be conclude that the different mangoes produced different types of wines including three yeast strains produced three wines with different characters. *Banginapalli* wines with yeast strain CFTRI 101 got the highest score obtained different followed by *Alphanso* and *Totapuri* (Table 4) (Reddy 2005 and Reddy *et al*., 2009).

Application of Immobilization in Mango wine production

Cell immobilization in alcoholic fermentation is a rapidly expanding research area because of its beneficial, technical and economic advantages compared to the conventional free cell system (Stewart an Russell, 1986). In order to satisfy the demand for natural products and combine it with consumer acceptance, some researchers have proposed the use of fruit pieces as cell immobilization carriers for wine and beer production (Kourkoutas *et al*., 2001; Bekatorou *et al*., 2002; Kourkoutas *et al*., 2003b; Tsakiris *et al*., 2004) and have reported products with fine taste and aroma and a distinct fruity character. This biocatalyst showed a good stability and produced wines with special flavour and improved quality.

The cell immobilization technology was also adopted in mango wine production and a novel yeast biocatalyst was prepared by using watermelon pieces as immobilizing support for yeast, *Saccharomyces cerevisiae* 101 strain for use in wine production. Immobilization was confirmed by electron microscopy (Figure 2) (Reddy 2005). Mango peel was also used as suppoting material and produced good quality mango wine (Varakumar *et al*., 2012). The fermentation rate and other parameters were compared with the free yeast cells at different temperatures. In all cases, fermentation time was short (22 h at 30°C and 80 h at 15 °C) and produced high ethanol productivities (4 g/l/h). The volatile compounds viz., methanol, ethyl acetate, propanol-1, isobutanol and amyl alcohols that were formed during fermentation were analyzed with help of the GC-FID. Cell metabolism of immobilized yeast was not much affected by immobilization. It was said that the immobilization of yeast on watermelon pieces increased the fermentation rate, vitality and viability of yeast cells. Preliminary sensory tests suggested that the fruity aroma, fine taste and the overall quality improved was of the produced wines.

Other fermented products from mango juice

Mango vermouth

The production of aromatic frutified wine from mango juice is known as mango vermouth (Onkarayya 1985; Onkarayya 1986 and Ossa *et al*., 1987). The base wine was made from *Banginapalli* cv. raising to 22 °Bx, adding 100 ppm SO_2, 0.5% pectinol enzyme and carrying fermentation at 22 ºC using Montrachet strain 522 of *S. cerevisiae*. The composition of mango vermouth in respect to pH, ethanol, total acidity, total phenols and aldehyde was comparable to vermouth prepared from grapes. The herbes and spices used in mango vermouth were balck pepper, coriander, cumin, Bishop's weed, clove, large cardamom, saffron, fenugreek, nutmeg, cinnamon, poppy seeds, ginger, lichen and flame of forest. The sensory evaluation testes suggested very good quality in comparison with grape vermouth.

Cost economics

Approximately 500 ml of juice can be obtained from 1 kg of mangoes. In order to produce 1 l of wine, it requires about 1250 ml juice, as there would be fermentation and evaporation losses. Thus, 2.5 kg of mangoes are required costing around Rs. 70.00 as the present raw material cost and about 40% of the raw material cost would be the processing cost. Hence 1 l of wine would cost approximately Rs. 100.00. However, scale-up studies need to be carried out for an actual assessment of the cost of production of mango wine.

Conclusions and future perspectives

Wines made from complete or partial alcoholic fermentation of grape or any other fruit contain ethyl alcohol essential elements, vitamins, sugars, acids, phenolics etc. Wines from fruits are preferable to distilled liquors for stimulatory and healthful properties. These beverages also serve as an important adjunct to the human diet by increasing the satisfaction and contribute to the relaxation necessary for proper digestion and absorption of food.

Fruits produced from tropics are highly perishable commodities and have to be either consumed immediately or preserved in one or the other form. In the developed countries, a considerable quantity of fruit is utilized, but in developing countries, lack of proper utilization results in considerable post harvest losses, estimated to be 30-40%. The increased production can be soaked profitably, if fruit wines are produced. Setting - up of fruit wineries besides industrialization of the fruit growing belts could result in economic upliftment of the people, generating employment opportunities and providing better returns of their produce to the orchardists. Availability of technology is the single important factor determining the production through cost and type of the product is also a significant consideration in popularising the product. So production of fruit wines in those countries where fruits other than grape are grown would certainly be advantageous. In future, it is necessary to conduct more studies on more varieties available in India regarding the physico-chemical composition, volatile composition and especially health beneficial effects of mango wine.

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