Journal of Applied Horticulture, 17(2): 145-150, 2015

Production, quality and aroma analysis of sapodilla (*Manilkara achras* (Mill) Fosb.) wine

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Abstract

Process was standardized for preparation of fermented beverage from sapodilla (*Manilkara achras* (Mill) Foseberg). The starter culture using yeast strain *Saccharomyces cerevisiae* UCD 522 fermented juice from two sapodilla varieties *viz.*, Cricket Ball and Oval, to obtain wines with 10.1-11.2 % alcohol, 0.44- 0.58 % acidity, 3.6-3.9 pH, 0.26-0.28 % residual sugar, 300-645 mg/L phenolics and <0.09 % volatile acidity in six to nine days at 18 °C. Retention of peel while pulping improved the phenolics level; but reduced the sensory quality of wine. Bentonite dosage and period required for clarification was optimized as 0.04 % for 14 days and 0.08 % for 21 days for production of wine from peeled fruits of Cricket Ball and Oval varieties, respectively. Sensory evaluation of dry, sweet, and flavored wines revealed the potential market acceptability of the wines. Head space volatile analysis showed the presence of new odorous compounds like esters and short chain fatty acids during vinification of sapodilla juice. Methoxy compounds and carbonyl fractions were less in the finished wine compared to natural juice.

Key words: Sapodilla, wine, yeast, phenolics, wine clarification, head space volatiles

Introduction

Sapodilla (*Manilkara achras* (Mill) Foseberg), also known as sapota, is a popular dessert fruit in tropical countries like Brazil, Guatemala and India with the centre of origin being in Mexico. The rapid increase in cultivation of this fruit crop is mainly due to its adaptability to wide range of conditions, low cost of production and high economic returns. Being climacteric, ripe fruits have shelf life ranging from 5-7 days and require quick disposal (Salunkhe and Desai, 1984). Ripe fruits of sapota are good source of digestible sugars (12-18%) and also contain 0.5 per cent protein, 1.1 % fat, 23 % carbohydrates, 1.6 % fiber and 0.4 % ash. They are also rich source of minerals like calcium, phosphorus and iron. The Cricket Ball and Oval varieties contain several amino acids like alanine, aspartic acid, glutamine, glutamic acid, lysine, phenylalanine and threonine. Additionally Cricket Ball contains glycine, isoleucine, proline, citrulline, α-aminobutyric acid and Oval contain arginine and valine (Gopalan *et al*., 1981).

Besides table purpose, ripe sapota fruits are also used for making value added products like intermediate moisture foods, beverages and bakery products (Relekar and Naik, 2012). Being sugar-rich, the fruit can be converted to fermented product like sapodilla wine. Impressive progress has been made in development of technologies for preparation of wines using fruits like mango, apple, pear, plum, pineapple, cashew-apple, banana, ber, strawberry, litchi etc. (Joshi and Attri, 2005). However, research work carried out on standardization of a suitable methodology for sapodilla wine is very limited and earlier work mainly focused on influence of fruit maturity and pectinase enzyme on sapota juice fermentation at room temperature (Pawar, 2009). Present paper describes the result of experiments on evaluation of popular sapodilla varieties for wine making, effect of fruit peel removal on wine quality, optimization of clarification agent, preparation of diverse styles of sapodilla wines, and analysis of head space volatiles of sapodilla juice and dry wine.

Materials and methods

Preprocessing operations: Two commercial varieties of sapodilla fruits *viz.,* Oval and Cricket Ball grown in India were obtained from the orchards of Indian Institute of Horticulture Research, Bangalore. The mature fruits were harvested, washed, surface dried and stored in open plastic trays lined with paper till they reached optimum ripe stage. Fully ripe sapodilla fruits were subjected to pre-processing operations like washing, separation of seeds and milky latex portion and pulping. Pulping of peeled and unpeeled fruits were done in different experiments for checking the effect of peel retention on the quality of wine. Pulp was liquefied using a commercial grade enzyme Pectinase CCM Plus (Biocon India Ltd) by adding at the rate of 5 mL/kg pulp followed by incubation at of 30 °C for 3 h. Juice was extracted by pressing this pulp in a muslin-cloth bag at the end of incubation period.

Chemical composition of pulp and juice: The composition and quality parameters like total soluble solids, acidity, pH, total phenolics and ash were determined in all treatments as per the standard procedures (Ranganna, 1986)

Fermentation of sapodilla juice: The expelled sapodilla juice was ameliorated by adjusting total soluble solids (T.S.S.) 22° Brix, and titratable acidity to 0.5 per cent by the addition of calculated amounts of cane sugar and tartaric acid. Dibasic ammonium phosphate (0.2g/L) was added as nitrogenous food for the yeast. Potassium metabisulphite (KMS) was added @ 200 ppm for inhibiting the growth of natural microflora and facilitating the growth of pure yeast culture as well as to prevent browning reactions during fermentation and storage. Log phase culture of the yeast *Saccharomyces cereviciae* UCD 522 (2%

v/v) with a population of 10^{12} cells/mL was inoculated to the ameliorated sapodilla juice and mixed well. The inoculated juice was fermented in BOD incubator at 18 °C till T.S.S. reduced to 0 °B. Total soluble solids (T.S.S.) was measured at regular intervals using Brix hydrometer. The completely fermented clear juice samples were separated from the sediment by siphoning, and were stored at 10±2 °C. The bottled wines were clarified by addition of bentonite (0.04 - 0.08%), clear wine samples were further racked, bottled and plugged with cork stoppers.

Analysis of wine: The biochemical parameters like pH, titratable acidity, volatile acidity, alcohol, phenolics and residual sugar were measured in the sapodilla wine as per the standard methods (Amerine and Ough, 1982). The clarity of the sapodilla wine was monitored by measuring the absorbance at 600 nm in UV-VIS spectrophotometer (Optima 300 plus).

Preparation of different types of sapodilla wine: The clarified base wine obtained by fermentation was fortified to contain varied flavour and sweetness. The flavoured wine (vermouth type) was prepared by adding coarsely ground mixture of spices in the clarified wine. These bottles were kept at 10±2 °C for 2 weeks and the spices were removed by filtration. The spices used for the preparation of flavoured wine were – ajwain (0.20 g/L), cinnamon (0.5 g/L), clove (0.3 g/L), coriander seeds (1 g/L), cardamom (0.20 g/L), nutmeg (0.50 g/L), cumin (0.20 g/L), anise (0.30 g/L), dried ginger (0.25 g/L), benzoin (0.05 g/L), black pepper (0.10 g/L), fenugreek seeds (0.10 g/L). Sweet wine was prepared by dissolving five per cent sucrose in base wine.

Sensory evaluation of wine samples: Sensory appeal of the wines were judged on a nine point Hedonic scale (1=Dislike extremely, 2= Dislike moderately, 3= Dislike, 4=Dislike slightly, 5= neither like nor dislike, 6 = like slightly, 7= like moderately, 8= like much, 9= like extremely)

Analysis of head space volatiles: The head space volatiles of the juice and dry wine from peeled fruits of sapodilla variety Cricket Ball was analyzed by SPME (GC-FID and GC-MS) method. Extraction process for head space volatiles of sapodilla fruit and wine was carried out as per the method suggested by Vermeir *et al.* (2009). Twenty milliliters of juice and wine sample were transferred to screw cap vials with silicon rubber septum and magnetic stirrer, to which sodium chloride was added. The SPME device (Supelco Inc. Bellefonte, PA, USA) coated with DVB/CAR/PDMS (50/30 µm, highly cross linked) fiber was conditioned by inserting it into the GC injector port at 260 °C for 2 hrs. The conditioned fiber was then inserted into the headspace under magnetic stirring for 90 min at 37 °C. Subsequently, the SPME device was introduced in the injector port for chromatographic analysis and was retained in the inlet for 5 min. The GC-FID analysis was performed on a Varian-3800 gas chromatograph system fitted with the DB-5 column having 30 m X 0.25 mm ID with 0.25 µm film thickness. The detector and injector temperature was 270 and 260 °C, respectively and the temperature of the column was raised from 50 °C to 200 °C with an increment of 3 °C /min with a holding time for 3 minutes, followed by a rise of 10 °C/min to 220 °C and maintaining the constant temperature for 8 minutes. The carrier gas was helium at a 1.0 mL/min flow and split 1:5. For the qualitative identification of volatile substances and comparative variation of retention time and index, the standard compounds *viz*., ethyl acetate, propanol, isobutanol, butanol, amyl alcohols, isoamyl acetate, pentanol, hexanol, 1-octene-3-ol, eugenol were co-chromatographed. Volatile compounds were identified with a ion trap Varian 4000 GC-MS/MS mass selective detector using VF-5MS, 30 m X 0.25 mm ID with 0.25 µm film thickness column. The mass spectrometer was operated in the external electron ionisation mode. The carrier gas used was helium @ 1 mL/min. The injector temperature was 250 °C; trap temperature was 220 °C, and the ion source-heating at 230 °C, transfer line temperature 250 °C, EI-mode was 70 eV, and the full scan-range 50-450 amu. The column temperature was programmed same as described above. The total volatile production was estimated by the sum of all GC-FID peak areas in the chromatogram and individual compounds were quantified as relative percent area. Volatile compounds were identified by comparing the retention index which was determined by using homologous series of n-alkanes (C_5 to C_{32}) as standard (Kovats, 1965) and comparing the spectra available with two spectral libraries using Wiley and NIST-2007.

Results and discussion

Rate of alcoholic fermentation and quality of wine is mainly influenced by the chemical composition of juice fermented. The carbohydrates, mainly sugars, act as substrates for fermentation by yeast for production of alcohol and carbon dioxide. Very high quantity of sugars leave higher proportion of non alcoholic residues in wine (Amerine and Ough, 1982). In the present study, juice obtained from two popular sapodilla varieties *viz*. Cricket Ball and Oval which were used for wine making were analyzed for the essential characteristics for wine making (Table 1). T.S.S. ranged from 19.8-24 °B, titratable acidity of the juice of Oval and Cricket Ball were 0.36 to 0.42 per cent, with pH ranging from 4.7 to 5.3. The ash content of pulp and juice of peeled Oval and Cricket Ball varieties ranged between 0.47 to 0.55 per cent. The amount of total phenolics was highest in juice of unpeeled Oval fruit (720 mg/L) and lowest in peeled Cricket Ball (496 mg/L). Sapodilla, commonly used as a dessert fruit is rich in sugars with a T.S.S. ranging from 21-28° Brix (Gopalan *et al*., 1981). Commercial standards suggest 0.5-0.6 per cent acidity and 3.5-4.0 pH in good quality grape wines (Amerine and Ough, 1982). Both the varieties recorded a lower acidity indicating the need of acidity amelioration which would also bring down the pH to optimum level. The fruit also possessed some quantity of phenolics which could bring in mild astringency to the finished product on fermentation. Based on the above observations, it is suggested that sapodilla fruits are good raw materials for the production of wines.

Effect of fruit peel removal on the quality of wine: Sapodilla peel is edible and has more nutritive value than pulp (Gopalan *et al*., 1981); and the use of unpeeled fruits for juicing can reduce the labor cost, thus lowering the cost of production. Mechanization of peeling is difficult due to the soft texture of ripe fruits. Keeping this in view, juice extracted from peeled and unpeeled fruits were included in the study. Fermentation started faster in juice from peeled fruits of Cricket Ball variety and completed in six to seven days (Fig. 1). There was a delay in the initiation of fermentation in juice from Oval variety, and juice from unpeeled fruits. This observation suggests that Cricket Ball

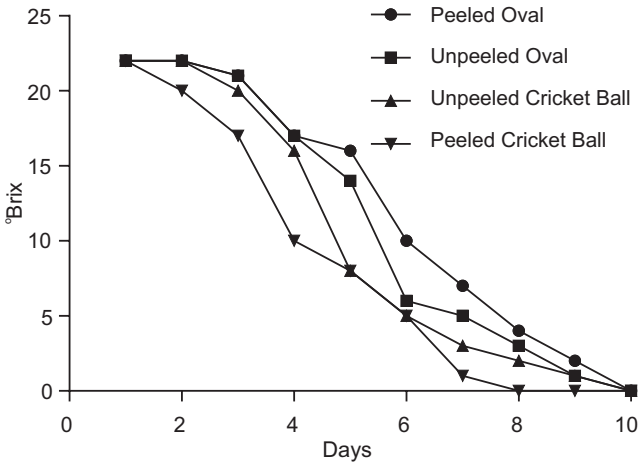

Fig. 1. Fermentation of juice from peeled and unpeeled sapodilla fruits

variety is suitable for fermentation as the risk of out growth of natural yeast is minimized and a faster completion of fermentation is achieved. The absence of fast initiation of fermentation results in stuck and sluggish fermentation due to the multiplication of the natural flora (Bisson and Butzke, 2000). The composition and sensory score of wines made from the unpeeled and peeled fruit juice is given in Table 2. A marked increase in the phenolics, volatile acidity; as well as a low sensory score were noticed in wines from unpeeled fruits. High volatile acidity is a negative attribute of wine quality, and results mainly due to acetic acid formation. The probable reason of high volatile acidity would be the presence and subsequent metabolic activities of undesirable surface microflora harboured by the fruits. The fruit surfaces are usually contaminated with undesirable acetic acid producing yeasts and bacteria and other spoilage micro organisms such as lactic acid bacteria and molds, which are acquired either from the field or during harvesting and further handling operations (Frazier, 1995). Undesirable micro flora and the inhibitory compounds in the peel would have retarded the fermentation in starter culture. Based on these results, it is concluded that removal of skin prior to pulping is essential to get good quality wine from sapodilla fruits.

Standardisation of clarification agent dosage: The suspended particles originating from juice and yeast cause haziness in wine, which is an undesirable attribute. An attempt was made in the study to optimize the dose of clarification agent, bentonite, in sapodilla wine. Bentonite treatment did not alter the chemical composition of the base wine, but had a positive effect on color and clarity, which in turn could contribute to higher score for visual appearance and taste (Table 3 and 4). Bentonite dosage at the rate of 0.04 % was sufficient to obtain a clear product within 14 days in Cricket Ball variety; while 0.08% and an incubation period of 21 days was required for obtaining clear wine in Oval variety. The observed difference in the clarification time is probably due to the difference in the pulp texture. Cricket Ball variety has coarse, gritty pulp and Oval is known to possess soft, mellow pulp. Bentonite is an inexpensive monmorrillanite clay used for grape wine clarification. It can remove heat-stable proteins, unwanted metals like Cu, Fe, and Zn from the colloids in a dose dependant manner (Amerine *et al*., 1980).

Composition and sensory quality of different types of sapodilla wine: Chemical composition of different types of sapodilla wine is presented in Table 5. Sweet wine possessed > 5% residual sugar, and the other types were fermented till dryness. The phenolic content in the flavoured wine was high, which could be due to the extraction of phenolic compounds from the added flavouring agents. Spices are rich in antioxidant compounds like vitamins, flavanoids, terpenoids, phytoestrogens etc (Suhaj, 2006). Different sapodilla wines were subjected to sensory evaluation to assess the acceptance among the consumers. The wines were golden yellow in color resembling white grape wine, possessed appealing aroma, and scored 6.6 to 7.9 for their overall acceptance on a nine point hedonic scale. Flavoured wines (vermouths) contain herbs and spices with medicinal properties and are more beneficial for health (Panesar *et al*., 2011). Ingredient herbs in the

Table 1. Proximate composition of juice from sapodilla varieties used for wine making

Parameter	Cricket Ball		Oval	
	Peeled	Unpeeled	Peeled	Unpeeled
TSS (°Brix)	24.00±0.30	20.00±0.4	23.30±0.2	19.80±0.3
Total sugar (%)	21.60±0.56	19.30±0.2	21.54±0.2	17.41±0.29
pH	4.80±0.10	4.90±0.1	4.70±0.2	4.70±0.2
Titratable acidity (%)	0.36±0.04	0.25±.03	0.42±0.1	0.21±0.05
Phenolics (mg/L)	496±20	670±24	521±19	720±25
Ash (%)	0.76±0.01	0.89±0.1	0.47±0.09	0.55±0.06

Values given are mean of triplicates ± standard deviation

Table 2. Composition of wine prepared using juice obtained from peeled and unpeeled sapodilla fruits

Parameters	Cricket Ball		Oval	
	Peeled	Unpeeled	Peeled	Unpeeled
pH	3.9±0.15	3.8±0.08	3.6±0.00	3.6±0.09
Total titratable acidity (%)	0.44±0.01	0.51±0.01	0.57±0.02	0.58±0.04
Residual sugar (%)	0.26±0.00	0.32±0.00	0.28±0.00	0.29±0.01
Total phenolics (mg/L)	300±10.9	396±16.3	402±19.3	645±19.2
Alcohol (%)	10.9±0.23	11.0±0.25	10.1±0.50	11.2±0.26
Volatile acidity (%)	0.048±0.00	0.092±0.01	0.036±0.00	0.045±0.00
Sensory score	7.0±0.46	4.2±0.97	6.7±0.31	3.7±0.52

Values given are mean of triplicates ± standard deviation

Table 3. Effect of bentonite dosage on the clarity of sapodilla fruit wine

Treatment	Turbidity				Visual appearance			
	14 days		21 days		14 days		21 days	
	Cricket Ball	Oval	Cricket Ball	Oval	Cricket Ball	Oval	Cricket Ball	Oval
Peeled, 0.08 %	0.022	0.063	0.015	0.061	+ + ++	+++-	++++	++++
Peeled, 0.04 %	0.025	0.106	0.020	0.100	++++	++--	++++	+++-
Peeled, 0.02 %	0.042	0.106	0.035	0.101	++--	++--	+++-	++--
Peeled, 0%	0.044	0.124	0.043	0.120	++--	++--	++--	++--
Unpeeled, 0.08%	0.065	0.058	0.064	0.052	++++	+++-	++++	++++
Unpeeled, 0.04 %	0.070	0.065	0.065	0.061	++++	++--	++++	+++-
Unpeeled, 0.02 %	0.090	0.069	0.072	0.063	+++-	++--	+++-	++--
Unpeeled, 0%	0.200	0.085	0.198	0.080	+++-	++--	+++-	++--

++-- = slightly clear, +++- = moderately clear; ++++ = clear; * values given in Table are mean of triplicates

Table 4. Effect of bentonite dosage on the composition of sapodilla fruit wine

Treatment	pH		Acidity (%)		Residual sugar (%)		Total phenolics (mg/L)		Alcohol (%)		Volatile Acidity (%)	
	a	b	a	b	a	b	a	b	a	b	a	b
Peeled, 0.08 %	3.86	3.6	0.51	0.57	0.28	0.282	396	402	11.0	10.1	0.092	0.036
Peeled, 0.04 %	3.93	3.6	0.48	0.60	0.28	0.283	398	410	10.9	10.0	0.096	0.048
Peeled, 0.02 %	3.89	3.6	0.49	0.58	0.28	0.285	400	450	10.8	10.0	0.04	0.054
Peeled, 0%	3.93	3.6	0.51	0.61	0.28	0.290	400	460	10.7	9.9	0.014	0.054
Unpeeled, 0.08%	3.84	3.60	0.40	0.58	0.28	0.281	300	645	11.0	11.2	0.090	0.054
Unpeeled, 0.04 %	3.83	3.6	0.42	0.60	0.28	0.281	310	645	10.9	11.0	0.084	0.042
Unpeeled, 0.02 %	3.89	3.60	0.42	0.60	0.28	0.283	310	650	11.1	10.9	0.09	0.048
Unpeeled, 0%	3.90	3.6	0.43	0.60	0.28	0.290	315	651	10.7	10.9	0.09	0.054

The values given in the table are mean of triplicates a: Cricket Ball, b: Oval

Table 5. Composition of dry and flavoured sapodilla fruit wine

Treatment		pH	Total acidity (% tartaric acid)	Alcohol (%v/v)	Residual sugar (%)	Phenolics (mg/L)	Volatile acidity (% acetic acid)	Sensory score
	Dry	3.92 ± .0	0.46 ± .02	10.9 ± 0.02	0.28 ± 0.01	300 ± 13.0	0.048 ± 0.00	7.0 ±.0.54
Cricket Ball	Sweet	3.81 ± 0.1	0.51 ± 0.01	11.6 ± 0.41	5.60 ± 0.61	312 ± 5.6	0.043 ± 0.00	8.0 ± 0.23
	Flavoured	3.9 ± 0..02	0.44 ± 0.04	11.7 ± 0.17	0.26 ± 0.06	408 ± 3.9	0.048 ± 0.00	7.7 ± 0.45
	Dry	3.6 ± 0.05	0.60 ± 0.02	10.1 ± 0.23	0.30 ± 0.10	402 ± 5.7	0.036 ± 0.00	6.3 ± 0.64
Oval	Sweet	3.68 ± 0.07	0.51 ± 0.06	10.9 ± 0.34	5.40 ± 0.54	392 ± 6.7	0.035 ± 0.00	7.2 ± 0.49
	Flavoured	3.6 ± 0.04	0.57 ± 0.04	11.9 ± .25	0.33 ± 0.01	532 ± 12.5	0.035 ± 0.00	7.5 ± 0.47

Values given are mean of triplicates ± standard deviation

study included antimicrobial spices like clove, antipyretics such as black pepper and ginger; and carminative agents like cumin and anise. It is likely that flavoured sapodilla wines also possess some medicinal properties.

Head space volatile composition of juice and dry wine from sapodilla var. Cricket Ball: Though the catabolism of hexoses into ethanol is the primary objective of fermentation, this process also results in production of several volatile compounds, produced as by-products of metabolic processes of yeast. Volatile composition changes considerably during the conversion of juice to wine, suggesting the formation of new compounds during the process (Schreier, 1979; Ebeler, 2001). Relative abundance of head space volatiles of juice and wine is given in the Table 6. The proportion of various functional compounds in the expelled juice followed the pattern esters > methoxy compounds > alcohols > aldehydes and ketones > acids > hydrocarbons; while in wine, the order of abundance was esters > acids > alcohols > methoxy compounds > aldehydes and ketones. Esters formed the major part in head spaces of both juice and wine with a higher proportion in wine. Methyl salicylate, 1-propyl ethanoate, 1-butyl butanoate, ethyl hexanoate, vinyl benzoate, benzene propyl acetate and ethyl hexadecanoate were the most predominant esters in juice. Earlier reports on sapodilla aroma analysis carried out by MacLeod and DeTraconis (1982) also identified methyl salicylate and methyl benzoate as major esters contributing to sapodilla aroma. Esters like ethyl hexadecanoate, ethyl dodecanoate, ethyl benzoate, methyl- 9 - octadecenoate, ethyl tetradecanoate, ethyl - cis, cis-9, 12-octadecadienoate were predominant in sapodilla wine head space. Several acidic compounds are known to be produced or modified during the course of yeast fermentation. These include volatile fatty acids of up to 12 carbons, primarily hexanoic, decanoic, and octanoic acids (Schreier, 1979). In the present study also, high amount of dodecanoic acid, pentadecanoic acid, 9-hexadecenoic acid and their esters were found in higher amounts in wine. Benzyl alcohol was the major hydroxyl compound in head space of sapodilla juice, and was reduced to negligible quantity in wine head space. Cis -methyl isoeugenol and benzene compounds

Table 6. Relative abundance of head space volatile compounds present in juice and wine from sapodilla variety Cricket Ball

Name of the compound	R.I.	Relative area %	
		Juice	Wine
Hydrocarbons			
o-Xylene	852	0.152	N.D
α-Pinene	938	0.074	0.019
α-Phellandrene	1010	0.087	N.D
α-Terpinene	1025	0.082	N.D
Limonene	1029	0.078	N.D
Ocimene	1039	0.069	0.018
Naphthalene	1182	0.721	N.D
Azulene	1310	N.D	0.424
α-Copaene	1368	0.159	0.114
α-Caryophyllene	1462	0.094	0.188
Calamenene	1521	0.177	N.D
Cadinene	1532	0.077	N.D
Total		1.770	0.764
Alcohols			
1-Hexen-3-ol	769	0.067	N.D
3, 4-Dimethyl-3-hexanol	845	N.D	0.164
2-Ethyl-2-hexanol	910	N.D	0.189
1, 2-Pentanediol	926	1.512	N.D
Benzyl Alcohol	1021	7.676	0.351
2-methyl butan-2-ol	1023	0.105	0.127
(Z)-5-Octen-1-ol	1052	0.420	N.D
Veratrol	1151	0.250	N.D
Lavandulol	1155	0.221	N.D
(E)-6-Nonen-1-ol	1167	0.718	N.D
4-Terpineol	1181	0.275	N.D
3-Isopropenyl-2-methylcyclohexanol	1209	0.337	N.D
α-Methylbenzeneethanol	1212	N.D	0.668
Benzenepropanol	1221	N.D	0.994
Nerol	1228	0.101	N.D
cis, trans-Nerolidol	1564	N.D	0.100
cis-(+)-Nerolidol	1537	N.D	0.227
(Z, E)-3, 13-Octadecadien-1-1ol	2078	N.D	0.227
Total		11.680	3.047
CarboxylicAcids			
Benzoic acid	1191	N.D	1.196
Dodecanoic acid	1566	N.D	2.408
Tetradecanoic acid	1760	0.011	1.363
Pentadecanoic acid	1806	N.D	2.598
9-Hexadecenoic acid	1898	0.054	2.236
Hexadecanoic acid	1961	0.070	0.017
14-Ethoxy-14-oxotetradecanoic acid	2135	N.D	0.040
Total		0.135	9.858
Esters			
Methyl propenoate	618	N.D	1.313
1-propyl ethanoate	712	3.784	0.094
Ethyl 3-methylpropionate	809	0.599	N.D
Isoamyl acetate	872	2.535	0.052
Methyl (2E)-4-hydroxy-2-butenoate	942	0.258	0.021
1-Butyl butanoate	975	6.571	0.000
Ethyl hexanoate	996	4.383	0.080
Ethyl 3-furoate	1002	N.D	0.007
Hexyl ethanoate	1018	0.718	N.D
Ethyl 2-furoate	1047	N.D	0.013
Methyl benzoate	1092	N.D	0.339
Vinyl benzoate	1150	8.555	N.D
Ethyl benzoate	1170	1.550	13.447
Methyl salicylate	1198	9.892	N.D
Ethyl octanoate	1238	N.D	1.378
Ethyl salicylate	1270	1.212	N.D
α-Terpinyl acetate	1352	0.120	N.D
Butyl benzoate	1352	1.011	0.057
Benzenepropyl acetate	1373	4.796	0.464
Ethyl 9-decenoate	1389	N.D	0.109
Ethyl hydrocinnamate	1390	N.D	3.051
Isoamyl benzoate	1415	N.D	0.070
Isoamyl octanoate	1450	N.D	0.175
Methyl dodecanoate	1531	N.D	1.239
Ethyl dodecanoate	1597	N.D	10.913
Isopentyl decanoate	1646	N.D	0.126
Methyl 2-methyltetradecanoate	1715	N.D	1.514
Methyl pentadecanoate	1784	N.D	1.018
Ethyl tetradecanoate	1793	N.D	4.687
Methyl (9Z)-9-hexadecenoate	1885	N.D	2.548
Methyl hexadecanoate	1890	N.D	0.215
Diisobutyl azelaate	1938	N.D	1.480
Ethyl hexadecanoate	1975	2.554	16.929
Isopropyl hexadecanoate	2014	N.D	0.029
Methyl 9-octadecenoate	2081	N.D	6.738
Ethyl heptadecanoate	2098	N.D	0.270
Methyl octadecanoate	2128	N.D	0.117
Ethyl cis, cis-9, 12-octadecadienoate	2155	N.D	3.377
Ethyl cis-9-octadecenoate	2180	N.D	0.574
Ethyl octadecanoate	2195	N.D	1.531
Methyl eicosa-7, 10, 13-trienoate	2300	N.D	0.011
Total		48.539	73.986
Aldehydes and ketones			
Isovaleraldehyde	632	0.024	N.D
(E)-2-Hexenal	851	0.191	N.D
3-methyl butanal	929	0.062	0.075
(E, E)-2, 4-Heptadienal	1016	0.151	N.D
2-Nonanone	1090	0.228	N.D
Benzenepropanal	1160	3.929	N.D
Pulegone	1176	0.119	0.036
Benzaldehyde	1497	0.386	0.420
(Z)-9, 17-Octadecadienal	1997	N.D	0.647
Total		5.090	1.179
Methoxy compounds			
p-Methylanisole	1026	0.081	N.D
Anethole	1287	0.391	0.948
Methyleugenol	1337	0.040	0.857
Eugenol	1384	0.037	0.574
5-Allyl-2-methoxyphenol	1411	0.981	0.261
cis-Methyl isoeugenol	1432	12.961	0.771
1-Methoxy-4-(4-methyl-4-pentenyl)benzene	1459	10.992	N.D
Methylisoeugenol	1490	0.081	N.D
3, 4, 5-Trimethoxyallylbenzene	1554	N.D	0.147
Total		25.565	3.558
1, 3-Dichlorobenzene	1002	0.110	N.D
5-Chloro-1H-indole	1368	N.D	0.136
Others		0.110	0.136

R.I. : Retention index; N.D.: Not detected

were earlier reported as important components of sapodilla fruits (Shivashankar *et al*., 2007). Benzene propanal was the major aldehyde in sapodilla juice, while it was undetectable in wine. Similar was the observation with respect to cis-methyl isoeugenol and 1-methoxy- 4-(4-4, methyl-4-pentenyl) benzene. The present observation on proportion of carbonyl compounds in sapodilla juice and wine supports the earlier reports on vulnerability of carbonyl compounds to losses during fermentation (Kotsteridis and Baumes, 2000).

Present study suggested the feasibility of a laboratory scale process for the preparation of high quality fermented beverage from sapodilla fruit. Fermentation of juice from peeled fruits of variety Cricket Ball using the yeast *Saccharomyces cerevisiae* UCD 522 for six to seven days followed by 0.04 % bentonite treatment for 14 days resulted in sapodilla wine; while, oval variety needed longer duration for fermentation and higher bentonite dosage or incubation period. It was also found that pulping and juice extraction from unpeeled fruits is not desirable as it could result lower consumer acceptability. All the three types *viz*., dry, sweet and flavoured wines were found to have high sensory appeal. Head space volatiles of sapodilla wine was very much different from unfermented juice, mainly due to formation of more esters and short chain fatty acids, as well as disappearance of carbonyl, methoxy, and hydroxyl compounds during fermentation. Most of these compounds are known to be highly aromatic, supporting the distinctiveness of the sapodilla wine from the unfermented juice.

Acknowledgements

The authors thank Dr. A.S. Sidhu, Director, IIHR, Bangalore for the facilities provided for research and Mr. C. Lokesh for technical assistance.

References

Amerine, M.A., H.W. Berg, R.E. Kunkee, C.S. Ough, V.L. Singleton and A.D. Webb, 1980. *The Technology of Wine Making.* 4th edition, AVI Publishing Company, Westport.

Amerine, M.A. and C.S. Ough, 1982. *Handbook of Methods For Analysis of Musts and Wines.* 1st Edition, Wiley – Interscience Publications, New York.

Bisson, L.F. and C.E. Butzke, 2000. Diagnosis and rectification of sluggish and stuck fermentations. *Amer. J. Enol. Vitic.,* 51(2): 168-177.

Ebeler, S.E. 2001. Analytical chemistry: Unlocking the secrets of wine flavor. *Fd. Rev. Intl.,* 17: 45-64.

Fraizer, W.C. and D.C.Westhoff, 1995. *Food Microbiology*. Tata McGraw Hill Publishing company Ltd, New Delhi, India.

Gopalan, C.B.N., B.V.R. Ramasastri and S.C. Bala Subramaniam, 1981. *Nutritive Value of Indian Food*, National Instiute of Nutrition, Indian Council for Medical Research, Hyderabad.

Joshi, V.K. and D. Attri, 2005. Panorama of wine research in India. *J. Sci. Indu. Res.,* 64: 9-18.

Kotseridis, Y. and R. Baumes, 2000. Identification of impact odorants in bordeaux red grape juice, in the commercial yeast used for its fermentation, and in the produced wine. *J. Agric. Fd Chem.,* 48: 400-406.

Kovats, E. 1965. Gas chromatographic characterization of organic substances in the retention index system. *Adv. Chrom.,* 1: 229-247.

MacLeod, A.J. and U. DeTraconis, 1982. Volatile flavour components of Sapodilla fruits. *J. Agric. Fd. Chem.,* 30: 515-517.

Panesar, P.S., V.K. Joshi, R. Panesar and G.S. Abrol, 2011. Vermouth: Technology of production and quality characteristics. In: *Advances in Food and Nutrition Research.* Vol.63 p. 255-280. R.S. Jckson (ed). Academic Press.

Pawar, C.D. 2009. *Standardisation of Wine Making Technology from Sapota (Manilkara achras (Mill) Forsberg*. Ph.D. Diss., University of Agricultural Sciences, Dharwad. 2009. 140 pp.

Ranganna, S. 1986. *Handbook of Analysis and Quality Control for Fruits and Vegetable Products*. Tata McGraw Hill Publishing Company Ltd., New Delhi.

Relekar, P. and A. Naik, 2012. *Value Added Products of Sapota (Manilkara achras (Mill) Foseberg : Standardization, Storage and Quality Analysis*. Lambert Academic Publishing.

Salunkhe, D.K. and B.B. Desai, 1984. Chemical control of loses. In: *Post Harvest Technology of Fruits.* Volume I : Boco Raton, F.L. (ed). CRC Press, Lodon.

Shivashankara, K.S., T.K. Roy and Y. Selvaraj, 2007. Volatile components of two sapodilla (*Achras sapota* L.) cultivars. *Ind. Perfumer,* 51: 44-47.

Schreier, P. 1979. Flavor Composition of Wines: A Review. *CRC Crit. Rev. Fd Sci. Nut.,* 12: 59-111.

Suhaj, M. 2006. Spices antioxidant isolation and their antiradical activity: A review. *J. Fd. Comp. Anal.,* 19: 531-547.

Vermeir, S., M.L.A.T.M. Hertog, K. Vankerschaver, R. Swennen, B.M. Nicolai and J. Lammertyn, 2009. Instrumental based flavour characterisation of banana fruit. *Fd. Sci. Technol.,* 42: 1647-1653.

Submitted: November, 2014; Revised: December, 2014;
Accepted: December, 2014