PROCESS STANDARDISATION AND QUALITY EVALUATION OF WINE FROM BANANA (*Musa spp.*)

By

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THESIS

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DECLARATION

I hereby declare that the thesis entitled **"Process standardisation and quality evaluation of wine from banana (*Musa spp.*)"** is a bonafide record of research work done by me during the course of research and the thesis has not been previously formed the basis for the award to me any degree, diploma, fellowship or other similar title, of any other University or Society.

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Introduction

1. INTRODUCTION

Horticulture crops play a vital role in Indian agriculture and economy. In the world scenario, India stands second with fruit production of 43.23 million tonnes in an area of 3.95 million ha (NHB, 2017). Due to improper post harvest handling there has been loss of 24-30% of the total production, resulting in wide gap between the gross production and net accessibility.

Banana is one amongst the oldest fruits familiar to humankind. Banana is also called as 'Apple of Paradise' and is botanically named '*Musa* spp'. Banana is one of the economically important tropical fruit crops of India and also of our State. In Kerala, banana covers an area of 81530 ha with a production of 122413 mt (NHB, 2017). It is considered as a major food crop for millions of people in the world and contributes significantly to food security. It has a rare combination of energy value, tissue building elements, protein, vitamins, minerals and components like vitamin C, vitamin B6 and potassium.

The medicinal value of banana has been found beneficial for the treatment of several health issues like, arthritis, constipation, gout, anaemia, intestinal disorders, kidney stones, tuberculosis, allergies and urinary disorders.

Banana is highly perishable in nature because of textural characteristics and high-water content. Postharvest losses of banana can be reduced by adopting proper post harvest management practices and processing into value added products. Fermentation is a viable technique in the development of new products with modified physicochemical and sensory qualities, especially flavour and nutritional components.

Fruit wines are undistilled alcoholic beverages usually made from grapes or other fruits such as apples, peaches, plums, apricots, banana etc. Wines prepared from fruits are often named after the fruits. Wine is a food with a flavour like fresh fruit which could be stored and transported under the existing conditions.

The nutritive value of wine is increased due to release of amino acids and other nutrients by yeast during fermentation. Fruit wines contain 8 to 11 per cent alcohol and 2 to 3 per cent sugar with energy value ranging between 70 and 90 kcal per 100 ml.

Banana wine is a delicious alcoholic beverage with low alcohol content. It is obtained by fermentation of clarified juice at controlled temperature. The cost of production of banana based alcoholic beverages is much cheaper than other fruit based beverages. Hence, the present study is aimed at evaluating the popular banana varieties of Kerala for wine production and to evaluate the quality of wine during storage. The entire experiment has been conducted keeping in view the following objectives;

1. Evaluation of banana varieties for quality wine production
2. Quality evaluation of wine during storage/ageing

Review of literature

2. REVIEW OF LITERATURE

Among the tropical fruits, banana being the most widely grown and is cultivated in 130 countries. It is primarily used in dessert and cooking purposes. Banana is likewise known for its few restorative qualities. It is having high dietary benefit since its consumption will help intake of sugars, minerals, vitamins and fibers. Due to its high TSS content (21-24°B), medium acidity (0.4-0.6%) and pleasant flavour, it is suitable for beverage preparation (Perez *et al.*, 1997).

Significant losses have been reported in banana due to inadequate post-harvest handling practices. This is because that banana is biologically active and does transpiration, aging and other biochemical exercises even after harvest (Hailu, 2013). An extensive amount of marketable surplus fruits is accessible in all banana developing areas which should be handled and can be changed into processed products (Talla *et al.*, 2004).

Suneja (2004) revealed that, due to misusing, 25-40 percent of banana has been squandered and just 2 percent is prepared into processed products, the remaining being utilized in the crude form. This prompts inequality and fluctuation in prices and which brings loss to the farmers. So as to support income generation and development potential, it is fundamental to deliver value added products based on banana, with the goal that farmers get a guaranteed cost for their produce constantly.

Banana when converted into value added products such as juices or mixtures with other juices it can fetch good marketing price which will help banana farming community and also reduce banana post-harvest loss (Viquez *et al.*, 1981; Lee *et al.*, 2006).

Among the fruits used for production of fermented-distilled beverages (spirits) in Brazil, banana emerges out of them as best due to its high concentration of fermentable sugars (Silva, 2004).The presence of high sugar content in banana is reasonable for the generation of wine (Robinson, 2006). The significant amount of fermentable sugars present in peel and pulp of banana is utilized for alcoholic fermentation (Kordylas, 1990).

The literature available pertaining to the present study has been reviewed under the following heads;

2.1Biochemcial parameters of banana wine

2.1.1 Wine yield

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2.1Biochemcial parameters of banana wine

2.1.1 Wine yield

Brathwaite and Badrie (2001) reported that the pectinolase treated bananas with longer incubation period increased the wine yield (77.81%).The banana wine yield was higher (58ml/100ml of must) when banana must was treated with pectinolase enzyme (0.6%) (Ronnie *et al.,* 2001).

Waradai (2014) studied wine recovery (%) from blended wines made with different proportion of banana pulp and other fruit pulp (jamun, amla, papaya). The banana pulp alone gave the highest wine recovery (97.50%) when compared to other blended ratios of fruits.

Bhajipale (1997) reported that wines prepared from different ripening stages of karonda fruits yielded different quantities of wines. The fruits of mature green, partial ripe, ripe and over ripe gave wine yield of 640, 770, 426 and 438 ml per kg fruits respectively.

Ulla (2011) evaluated wine recovery (%) of pomegranate arils .The pomegranate arils treated with different concentrations of sugar syrup gave wine recovery which ranged from 66.02 to 67.25 percent.

Saritha (2011) evaluated the physico chemical and sensory qualities of banana wines with pure strains of wine yeast *Saccharomyces cerevisiae* and commercial baker's yeast. Wine yield was significantly high with baker's yeast in both 10^6 dilution (68.36%) and 10^7 dilution (67.76%). Among pure strains, wine yield was high with MTCC 172 (59.53 and 57.57%) respectively in both dilutions.

Byarugaba-Bazirake (2008) studied the effect of enzymatic processing on banana juice and wine. Wine yield was significantly high with banana pulp treated with yeast strain named VIN13-pPPK (60.3 ± 0.28%).

Pawar (2009) conducted work on wine making in sapota .The total wine recovery from must of sapota fruit ranged between 51.62 and 99.52 per cent.

2.1.2 pH

Satave and Pethe (2016) conducted a study to determine the effect of pH on physicochemical parameters of banana must after fermentation. The highest percentage of alcohol (7.32%) and titratable acidity (0.68 %) was found in must fermented at lower pH (3.0).

Ajith *et al.* (2018) studied the physico-chemical characteristics of wine prepared from banana and pineapple. The mixed fruit wine pH was acidic throughout the period of fermentation. The pH of the wine decreased from 4.5 to 2.0.

Ogodo *et al.* (2018) evaluated wine from mango cv Peter. Two sets of musts (A and B) were prepared. Wine A must was added with metabisulphate and starter culture. Whereas Wine B was fermented spontaneously without any addition. Both musts were kept for fermentation for 96 hours and their pH was recorded. There was decrease in the pH from 4.06 to 3.83 and 4.06 to 3.78 in the Wine A and B respectively.

Shwetha *et al.* (2016) conducted an experiment to study the preparation of wine from overripe bananas. Bananas were made into juice with dilution ratio of 1:3 with water and pulp and 5% sugar was added. There was reduction in the pH from 3.5 to 3.3 during the fermentation period.

Gavimath *et al.* (2012) reported the effect of pH on banana juice wine fermentation. Over ripened bananas were peeled off and made into pulp. There was a decline in the pH of banana must from 5 to 3 during the 30 days of fermentation period.

Nwobodo (2013) observed that pH of wine from banana decreased from 3.91 to 2.85 during 8 days of fermentation period.

Guava fruit wine was prepared using two strains of *Saccharomyces cerevisiae* NCIM 3095 and NCIM 3287 at different pH levels (2.5, 3.0, 3.5, 4.0, 4.5 and 5.0).At pH level 4.0, wine was found to give better results than the other levels (Sevda and Rodrigues 2011).

2.1.3 TSS

Onwuka and Awam (2001) evaluated physico-chemical characteristics of wines from different *Musa* species (cooking banana, plantain and banana). The TSS of wines of *Musa* species ranged from 8 ^{0} to 8.15 ^{0} Brix.

Brathwaite and Badrie (2003) determined the TSS of banana wines prepared using different ratios of fruit peel addition to its must. Peel addition (15%) resulted in higher T.S.S (9.07 ^{0}Brix) when compared with other wines (7.02- 7.57 ^{0}Brix).

Akbour *et al.* (2003) reported that the TSS decreased during fermentation of banana wine, which ranged from 18 ° Brix to 4.8 ° Brix which was kept for a period of 14 days.

Pandhre *et al.* (2010) studied on the physico-chemical characteristics of wine prepared from banana pulp. TSS of wine was found to be decreasing from 24^0 Brix to 9.2^0Brix during the period of fermentation.

Satave and Pethe (2016) determined the TSS of wines of banana which were prepared at different pH levels (3.0, 3.5, 4.0 and 4.5).The TSS of wines decreased gradually from 20 ^{0} Brix to 6.0 ^{0} Brix during 13 days of fermentation period.

Patil (1994) observed the TSS of wine prepared from four varieties of grapes. The must TSS level decreased from 23 ^{0} Brix to 8 ^{0} Brix during four days of fermentation.

Yadav *et al.* (2009) conducted an experiment on wine preparation from mahua. Wines were fermented to different TSS levels. The wine fermented to TSS 11^0 Brix was highly accepted when compared to other wines.

The total soluble solids (TSS) of wine A (fermentation with starter culture) and B (spontaneous fermentation) of mango were determined. The TSS was found to be 5 ^{0} Brix and 8 ^{0} Brix for wine A and B respectively (Ogodo *et al.*, 2018).

2.1.4 Titratable acidity

Brathwaite and Badrie (2001) evaluated the changes in banana wine quality. During the fermentation period (4 weeks), the titratable acidity (TA) gradually decreased from 0.60± 0.1% to

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0.12± 0.20%.There was no significant difference in titratable acidity during 3rd and 4th week of fermentation.

The titratable acidity of three different wines prepared from *Musa* species (cooking banana, plantain and banana) were estimated. The titrable acidity (g/l) of wines ranged from 1 to 1.19 (Onwuka and Awam, 2001).

Ngwang (2015) estimated the titratable acidity of wines produced from the long and short hand bananas. The short hand banana wine's, titratable acidity (mg/100ml) was higher (0.94 ±0.014) when compared to long hand banana wine (0.8±0.028).

The juice extracted from over ripe bananas were made into wine and kept for fermentation for stipulated period of time. There was increase in the titratable acidity (TA) from 1.01 to 1.36% (Shwetha *et al.,* 2016).

Kulkarni *et al*. (1980) conducted an experiment on wine produced from different cultivars of mango. Wine sample's titratable acidity ranged from 0.602 to 2.381 per cent.

Mohanty *et al*. (2005) prepared wine from the cashew apple juice with yeast *Saccharomyces cerevisiae* and evaluated physico-chemical characteristics. The titratable acidity increased from 0.24 ± 0.02 (g tartaric acid/100 mL) to 1.21 ± 0.06 (g tartaric acid/100 mL) in the wine.

Reddy and Reddy (2005) prepared wine from five different varieties of mangoes (Allampur Baneshan, Alphonso, Bangalora, Banganapalli, Neelam and Raspuri).The titratable acidity recorded from the wine samples of Allampur Baneshan, Alphonso, Bangalora, Banganapalli, Neelam and Raspuri were 0.61%, 0.65%, 0.62%, 0.605, 0.82% and 0.73% respectively.

2.1.5 Alcohol content

Banana must was treated with pectinase and α-amylase for gelatinizing pectin and starch. The enzyme treated banana wine yielded 13.9% alcohol (Cheirsilp and Umsakul, 2007).

Investigations carried out by Pandhre *et al.* (2010) with an aim to prepare wine from banana using wine yeast. The results revealed 8.2% alcohol content in banana wine.

Zaker *et al.* (2014) reported that pectinase enzyme treated banana wine had 14.5% alcohol content in it.

Banana peels were sliced into small pieces and boiled for hydrolysing the starch. The filtered extract was fermented by the wine yeast .The banana peel wine recorded 13.02% alcohol content in it (Byarugaba-Bazirake *et al.,* 2014).

Vaidya *et al.* (2009) recorded the alcohol content in kiwi fruit wine as 9.7%. The juice extracted was raised to 22^0 Brix with the addition of 100 ppm SO_2 and fermented with yeast *Saccharomyces cerevisiae* at 22^0 C.

Jamun wine from three varieties Jamun, Phaedra and Kathjamun recorded the alcohol content of 11.23, 10.93, and 10.71 per cent, respectively (Shukla *et al.*, 1991)

Investigations carried out by Sharma *et al.* (2009) showed that wines prepared from three different cultivars of strawberry recorded alcohol content ranging from 9.2-11.2%.

Gavimath *et al.* (2012) conducted comparative study of wines from fruits like banana, papaya, orange and lime. Alcohol content of fruit wine samples which were kept a month for aging was estimated. Banana wine had highest alcohol (15.49%) content when compared to papaya (8.73%), orange (8.63%) and lime (0.93%).

Sylvia (2016) conducted studies on wine from pineapple peel waste. Two types of wines were prepared from pineapple peel waste where in one was treated with bitter leaves whereas other one without bitter leaves. Both type wines were kept for 5 days of fermentation. The results revealed that treated wines (bitter leaves) had higher amount of alcohol (0.68%) than the one without bitter leaves (0.038 – 0.26%).

2.1.6 Reducing sugars, non-reducing sugars and total sugars

Over ripe banana fruits were used for making wine. The wine obtained from it was analysed and residual sugar was found to be 3.18 ± 0.16% (Kotecha *et al.*, 1994)

Fruits of banana, watermelon and papaya were used in preparing wine. Four types of wine were prepared by blending two fruits together (A,B,C,D) A -papaya and watermelon wine, B-papaya and banana wine, C-papaya, banana and watermelon wine, D- banana and watermelon wine. The total sugar (%) of A, B, C and D were analysed and they were 0.77 ± 0.02, 0.94 ± 0.02, 0.64 ± 0.02 and 0.54 ± 0.02 respectively (Ogodo *et al.,* 2015).

Sharma *et al.* (2004) reported that the concentration of reducing sugar decreased in jackfruit wine during 21 days of fermentation from 19 to 1.05 percent which indicated that increase in alcohol content of wine from 8 to 16 percent was due to rapid fermentation of sugar.

Fresh litchi juice was extracted from the fruits and was added with SO_2 (60ppm) and fermented with active yeast (150 ppm) .The pH was adjusted to lower than 3.8. The total and reducing sugars were found to be 2.1 g/l and 1.6 g/l respectively (Zeng *et al.,* 2008).

Pulp of custard apple were diluted with different ratios of water in order to prepare wine. Must dilution with water were 1:2, 1:3 and 1:4. The reducing sugar values ranged from 1.91 to 2.69 % (Kumar *et al.,* 2011)

The amount of total sugar in jamun wine prepared by different dilution (1:0.5, 1:1 and 1:2) ranged from 8.5 to 10.4 percent (Joshi *et al.,* 2012).

Mango wine prepared by using different varieties (Alphonso, Banganapalli, Raspuri, Neelam, Himam Pasand, Rumani, Totapuri and Sindhoora) had the residual sugars (g/l) ranging from 4.0 to 4.5 (Kumar *et al.,* 2012).

Machamangalath *et al.* (2016) analysed eight samples of blended wine of kokum and banana in different ratios and noted that the samples with 1:1 ratio was best. The wine with 1:1 fruit blend had total sugar of 220 g/l and residual sugar of 69 g/l.

2.1.7 Vitamin C

Akbour *et al.* (2003) compared the ascorbic acid (mg/100ml) content of banana wine and juice and found that juice had higher ascorbic acid (9.0 ± 0.01) content when compared to that of the wine (1.4 ± 0.0) .

Carambola wines prepared with six different concentrations of total soluble solids(TSS) viz. 18°, 20°, 22°,24°and 26° brix had the ascorbic acid content ranging from 107 to 182 mg/1000ml. The control recorded the highest ascorbic acid content (182mg/1000ml) (Lakshmana *et al.,* 2010).

Wines of pineapple *cvs.* Kew and Queen were analysed for the ascorbic acid content. Musts obtained from the Kew fruits were classified as T_1 (addition of DAHP) and T_2 (without DAHP) whereas, musts of Queen Fruits were classified as T_3 (addition of DAHP) and T_4 (without DAHP).Ascorbic acid content (% v/v) of the wines T_1, T_2, T_3 and T_4 were 18.70, 15.40, 21.76 and 19.50 respectively (Attri, 2012).

Tendu (*Diospyros melanoxylon*) fruit pulps were crushed and juice was extracted and fermented with yeast for 7 days at ambient temperature. The ascorbic acid (mg/g) content of must and wine were 2.00±0.05 and 1.52±0.22 respectively. It indicates that ascorbic acid shows a decreasing trend during fermentation of the must into wine (Sahu *et al.,* 2012).

Bael fruit wine was prepared by extraction of juice from the crushed pulp with addition of sodium metabisulphite (100 µg/ml) and kept for fermentation for 7 days. The wine was evaluated for the ascorbic acid content which was found to be 80.00 ±0.01 mg/100 ml (Panda *et al.,* 2013).

Must of sapota was produced by the extracted juice from the pulp and fermented into wine. Ascorbic acid (Vitamin C) content of the must was 2.86±0.21 (mg/100 ml) and it was reduced to 1.78±0.14 (mg/100 ml) in the wine (Panda *et al.,* 2014).

Panda *et al.* (2016) reported that the ascorbic acid content of wine produced from pulp of jackfruit was found to be 1.78 ± 0.24 mg/100 ml.

2.1.8 Total phenols

Ranjitha *et al.* (2015) estimated the total phenols (mg/l) in banana wine prepared from different yeast (*Saccharomyces cerevisiae*) strains. The total phenols of the wine ranged from 656 to 689 (mg/l).

Investigations carried out by Mohanty *et al.* (2005) revealed that there was not much change in the total phenol content of cashew apple wine during the fermentation period. The phenolic content was found to be lower (0.12 ± 0.03 g/100mL) when compared with grape wine (0.22 ± 0.00 g/100mL).

A red wine was prepared from jamun fruit and its biochemical characteristics were compared with commercially prepared wine from grapes. The phenol content of both wines were estimated and was found to be similar (0.22 ± 0.00 g /100ml) (Chowdary and Ray, 2007).

Wine was prepared from the juice extracted from orange cv Kozan and fermented for a period of time and analysed for the phenolic content. The total phenol content of the wine was found to be 162.68 mg/l in wine (Kelebek *et al.*, 2009).

Pino and Queris (2010) carried out studies on preparation and evaluation of wine from pineapple and observed that the phenol content of pineapple wine was 108.0(mg/l as gallic acid).

Sun *et al.* (2011) evaluated cherry wine samples using six different yeast strains. The total phenolic content of wines ranged from 584.3 to 742.7 mg GAE/L.

Jagtap *et al.* (2011) analysed the total phenol content in jackfruit wine. The total phenol content of 0.053 ± 0.00 mg/ml was found in jackfruit wine after 12 days of fermentation.

Panda *et al.* (2014) analysed the phenol content of wine samples prepared from the pulp of sapota fruits. The total phenolic content of wine was 0.21 g/100 ml. The pH of the wine played an important role in stability of the phenol components. As, there was increase in the pH of wine polyphenols got auto oxidised.

2.1.9 Yeast strain and population

Yeast strain that was isolated from the palm wine (*Elaeis guineensis*) gave better results in pineapple wine production when compared with commercial yeast (Ayogu, 1999).

Chilaka *et al.* (2010) reported that yeast strains (*S. cerevisiae, Schizosaccharomyces octoporus, Pichia* spp and *Saccharomyces paradoxus*) obtained from palm wine (*Elaeis* spp) can be used in the production of fruit wine which are acceptable.

Alvarenga *et al.* (2011) conducted an experiment on fermentation behaviour of the different yeast strains *Saccharomyces cerevisiae* (UNICAMPV1, UFMG-A905, UFMG-A1007, UFMG-A1240) on banana pulp and compared with commercial baker's yeast. Among them, *S. cerevisiae* strain UNICAMP-V1 and the commercial yeast had better fermentation behaviour when compared to others.

Sevda and Rodrigues (2011) conducted a comparative study of *Saccharomyces cerevisiae* strains (NCIM 3095 and NCIM 3287) in fermentation of guava fruit wine. The strain NCIM 3095 gave better quality wine compared to that of NCIM 3287.

Fermentation studies were carried out in Cavendish banana cv Robusta with various strains of yeast viz., *Saccharomyces cerevisiae* UCD522, MSU4, Dr. Alex and *S. fermentatii* UCD519 out of which *Saccharomyces cerevisiae* UCD522 and *S. fermentatii* UCD519 were found to be best starter culture and had better performance in alcohol production (Ranjitha *et al*., 2015).

Yeast cell count (cfu/ml) was done in wine prepared from banana juice and results were recorded on the 2nd, 4th, 6th and 8th day of must fermentation period. It was found that cell count increased from 4.5 x 10^7 to 5.0 x10^7 on 4th day and got reduced to 4.8 x 10^7 on 8th day (Nwobodo, 2013).

Two different yeast strains collected from NCIM, Pune were utilized for the fermentation of banana and its physicochemical characteristics were examined. The strains NCIM 3215 and NCIM 3604 did not show much difference in physicochemical characteristics of wine (Satave and Pethe, 2016).

Wei *et al*. (2019) evaluated the physicochemical properties of wine samples prepared from the different fruit sources (Apple, pear, grapes and kiwifruit) which were fermented with different non-*Saccharomyces* yeasts. The results showed that *Pichia kluyveri* X31-10 (Pk31) was the suitable strain for apple juice fermentation.

2.1.10 Microbial studies

Population of bacteria, fungus and yeast was evaluated in banana wine. The results showed that there was decreasing trend of bacteria, fungus and yeast from the initial to end of the storage which implied that wine was free of contamination (Saritha, 2011).

Sahu *et al*, (2012) reported that there was absence of bacteria, fungi and other spoilage microorganisms except *Saccharomyces cerevisiae* during the fermentation period of tendu fruit wine. It was due to addition of KMS (Potassium meta bisulphate) which suppressed the other spoilage microorganisms except *Saccharomyces cerevisiae* (Winter *et al.*, 2011).

The Microbial load (cfu/ml) of banana wines (*Musa sapentium)* was analysed. The results showed that it ranged from 9.38 to 8.20 cfu/ml (Idise, 2011).

The total bacterial count (cfu/ml) was taken in both controlled fermentation and self-fermented cashew apple wine. Microbial spoilage was more in self-fermented cashew apple wine whereas, wine from controlled fermentation showed nil presence of spoilage microorganism (Joseph, 2010).

Two set of mango wines were prepared where in one set was fermented with baker's yeast and another one was fermented spontaneously. Microbial analysis showed that baker's yeast wine was free of *Lactobacillus* species and *Candida tropicalis,* whereas the other one had presence of both microorganisms (Ogodo, 2017).

2.1.11 Energy

Calorific value of Garcinia wine was evaluated at different days of fermentation period. The results revealed that the calorific value increased from 71.6 kcal (Day 0) to 86.32 kcal (Day 21). Increase in calorific value was due to increase in the reducing sugars (Rai *et al.,* 2010).

The energy value of non fermented beverage was calculated from banana plantain and the calorie value of the beverage was low (79.28 kcal/g) due to low content of fat in it (Akubor, 2005).

2.1.12 Flavour profile

Ranjitha *et al.* (2013) carried out a comparative study of aroma profile of juice and wine from banana cv Robusta. Fermentation process led to loss and production of many aroma compounds. The results obtained showed that wine had synthesized decanoic, dodecanoic acid, hexa decanoic acid esters, and, highly odorous compounds like methyl nonyl ketone and isoeuginol, 2 methoxy 4-vinyl phenol. The aroma compounds like isoamyl acetate, butyl isovalerate, isopentyl isovalerate, trans-2-hexenal, butanoates, which were significant in banana juice was found to be of low quantity in the wine.

A composite wine was produced from banana and orange and its flavour profile was analysed. Total sixteen compounds were recognised and among them alcohols formed major portion (79.43%) followed by esters (15.14%) and acid (1.58%). Since the major portion of composite wine was composed of alcohols and esters, it had the special, pleasant aroma (Deng *et al.,* 2016).

The three red cultivars of grapes (Caiño Tinto, Caiño Longo, and Caiño Bravo) were analysed for the aroma compounds synthesized during fermentation. Among them Caíño Longo wine was the most aromatic since it had higher amount of acetates and esters when compared to the other two cultivars (Vilanova *et al.,* 2007).

Mango wine was analyzed for the compounds responsible for its aroma. The results indicated that ethyl butanoate and decanal were the major compounds which imparted the unique aroma to it (Pino and Queris, 2011).

The flavour profile of wines synthesized from ponkan (*Citrus poonensis*) using various strains of yeasts was investigated. The results indicated that wine produced from the yeast strain HF-08 had dominant quantity of aroma compounds when compared with others. The wine composed of aroma compounds from citrus fruit and also aroma synthesized from the yeast strains (Lee *et al.,* 2013).

2.1.13 Sensory evaluation

Akbour *et al.* (2003) reported that wines prepared from banana juice were found to be acceptable. Sensory evaluation was carried out and its results were compared with (reference) German wine and there was not much difference in flavour, taste, clarity and overall acceptability between both the wines.

Organoleptic evaluation of banana wine and papaya wine was carried out and scores were compared. The colour, taste, texture and overall acceptability score of banana wine was higher when compared with papaya wine (Egwim *et al.,* 2013).

Litchi wines were prepared by utilizing three yeast strains (UFLA CA11, UFLA CA1183, and UFLA CA1174) through spontaneous fermentation and the sensory evaluation of wine was carried out. Based on the scores, wine produced from the strain UFLA CA1183 obtained highest score (Alves *et al.,* 2011).

The organoleptic evaluation revealed that mango and pineapple peel composite wine had higher scores in terms of aroma, sweetness, mouth feel, alcohol strength, acidity and overall acceptability when compared with wines produced from pineapple peel and mango peel,separately (Balamaze and Wambete, 2017).

Davidovic *et al.* (2017) conducted sensory evaluation of wine prepared from peach cv Red Haven and compared with white grape wines. The results indicated that the peach wine had higher scores when compared with white grape wine in terms of acceptability.

2.1.14 Economics

The cost of production of banana wine was evaluated and its price was compared with commercial grape wine. Banana wine fetched lower price (Rs.96) when compared with 750ml of grape wine which cost Rs.150 (Saritha, 2011).

Investigations carried out by Reddy and Reddy (2005), found that around 500 ml of juice can be produced from 1kg of Mango fruits. In order to produce 1250ml of juice it required 2.5kg of fruits. The processing cost was 40% of the raw material cost. The final cost of 1ltr mango wine was calculated and found to be Rs 35.

The cost of preparation of wine produced from 1kg of pomegranate arils was calculated by finding out the price of pomegranate arils, man power, sugar and bottles. The total cost of production of 1 litre wine was Rs 172 (Ulla, 2011).

Jamun wine was produced and its cost of production was calculated. The total cost was evaluated by calculating the cost of fruits, chemicals, labour charge, bottles and sugar. One litre of jamun wine fetched a price of Rs 495 (Pimple, 2013).

Materials and Methods

3. MATERIALS AND METHODS

MATERIALS

The present investigation "Process standardisation and quality evaluation of wine from banana (*Musa spp*.) was carried out with different varieties of banana. The investigation was carried out in the Department of Post Harvest Technology, College of Horticulture, Vellanikkara, Thrissur during 2017-2019.

METHODS

The study was conducted under two experiments viz (3.1) Evaluation of banana varieties for quality wine production. (3.2) Quality evaluation of wine during storage/ageing. To support the aforesaid aspects of the investigation, various physico-chemical parameters were analysed and accordingly, the results were interpreted.

3.1 EVALUATION OF BANANA VARIETIES FOR QUALITY WINE PRODUCTION

3.1.1 Collection of banana fruits

The different banana varieties (Grand Naine, Karpooravalli, Poovan, Yangambi (KM-5) and Palayankodan) were collected from various localities of Thrissur.

3.1.2 Layout

The experiment was laid out in a Completely Randomized Design (CRD) with two replications each.

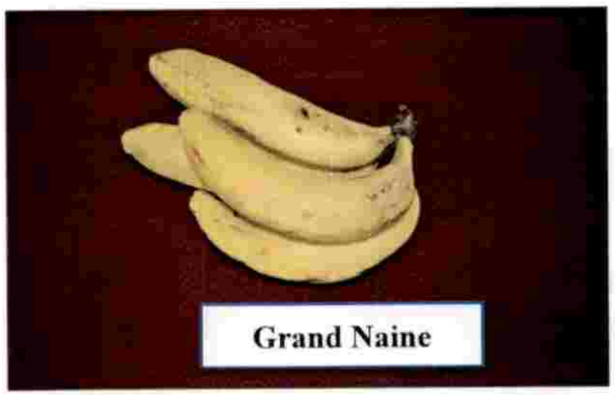


Plate 1: Banana varieties

3.1.3 Collection and preparation of starter culture with pure strain

The yeast strain *Saccharomyces cerevisiae* MTCC 4793 were procured from the Institute of Microbial Technology (IMTECH) Chandigarh, Punjab. Vacuum sealed glass ampules which contained freeze dried yeast were subcultured in a growth medium with the following composition;

Yeast extract	3.0 g
Peptone	10.0 g
Dextrose	20.0 g
Agar	15.0 g
Distilled water	1.0 L

The media was sterilized and then dispensed in Petri plates. Single colonies of the culture were uniformly suspended in sterile water. A loopful of the suspension was streaked on Petri plates. The procedure was done aseptically in a laminar airflow chamber. The slants were inoculated with a loopful of pure culture of *Saccharomyces cerevisiae* var. *ellipsoideus* (MTCC 4793) under aseptic conditions in laminar air flow and incubated at 28 ± 2ºC for 48 h in an incubator and stored in refrigerator at 0 to 5 ºC until used for fermentation.

3.1.4 Preparation of starter culture with baker's yeast

Sugar was dissolved in luke warm water at the rate of 10 g per 100 ml of water. Baker's yeast was then added at 5 g per 100 ml of the sugar solution. The culture was kept as such for 30 minutes for vigorous frothing. Population was enumerated by serial dilution plating on the Sabouraud's Dextrose Agar media contained in petri plates. The Petriplates were incubated at room temperature for 4 to 5 days. The colonies developed were counted and expressed as cfu/ml of the sample.

3.1.5 Preparation of wine

Ripe fruits of banana varieties after removal of peel, were sliced into smaller pieces and added with boiled and cooled water in 1:1 and 1:2 ratio. The TSS content of the substrate was raised to 20° brix by adding cane sugar, followed by addition of yeast (1.25g/l). The must was treated with (KMS) potassium metabisulphate (0.05g/l) for the inhibition of other microorganisms. The entire mass was allowed to ferment for 15 days under anaerobic condition in china clay jar and clarifying agent (egg white) was added at the rate of 1 egg white for 1 litre and it was filtered after one week. Clarified wine was evaluated for its quality.

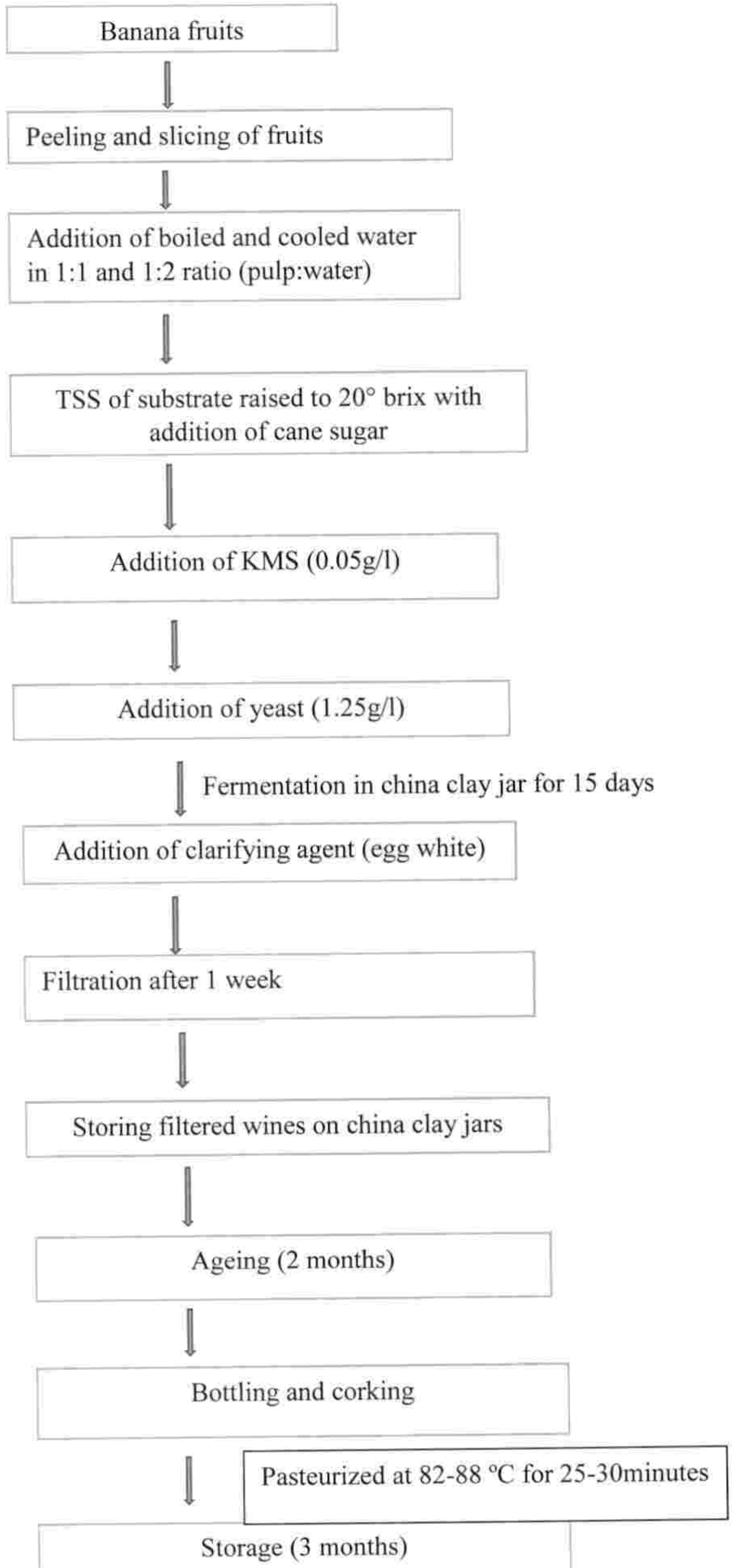
Collection

Mass multiplication

Inoculation

Colony formation

Plate 2: Culturing of MTCC 4793


Banana fruits
Peeling and slicing of fruits
Addition of boiled and cooled water in 1:1 and 1:2 ratio (pulp:water)
TSS of substrate raised to 20° brix with addition of cane sugar
Addition of KMS (0.05g/l)
Addition of yeast (1.25g/l)
Fermentation in china clay jar for 15 days
Addition of clarifying agent (egg white)
Filtration after 1 week
Storing filtered wines on china clay jars
Ageing (2 months)
Bottling and corking
Pasteurized at 82-88 °C for 25-30minutes
Storage (3 months)

The treatments involved in the experiment are detailed below

T1-Grand Naine 1kg pulp+1ltr of water (1:1) +Baker's yeast

T2- Grand Naine 1kg pulp+2 ltr of water (1:2) +Baker's yeast

T3- Poovan 1kg pulp+1ltr of water (1:1) +Baker's yeast

T4- Poovan 1kg pulp+2 ltr of water (1:2) +Baker's yeast

T5- Karpooravalli 1kg pulp+1ltr of water (1:1) +Baker's yeast

T6- Karpooravalli 1kg pulp+2 ltr of water (1:2) +Baker's yeast

T7- Yangambi KM-5 1kg pulp+1ltr of water (1:1) +Baker's yeast

T8- Yangambi KM-5 1kg pulp+2 ltr of water (1:2) +Baker's yeast

T9- Palayankodan 1kg pulp+1ltr of water (1:1) +Baker's yeast

T10-Palayankodan 1kg pulp+2 ltr of water (1:2) +Baker's yeast

T11- Grand Naine 1kg pulp+1ltr of water (1:1) +Pure strain of yeast (MTCC 4793)

T12- Grand Naine 1kg pulp+2 ltr of water (1:2) +Pure strain of yeast (MTCC 4793)

T13- Poovan 1kg pulp+1 ltr of water (1:1) + Pure strain of yeast (MTCC 4793)

T14- Poovan 1kg pulp+2 ltr of water (1:2) + Pure strain of yeast (MTCC 4793)

T15- Karpooravalli 1kg pulp+1ltr of water (1:1) +Pure strain of yeast (MTCC 4793)

T16- Karpooravalli 1kg pulp+2 ltr of water (1:2) +Pure strain of yeast (MTCC 4793)

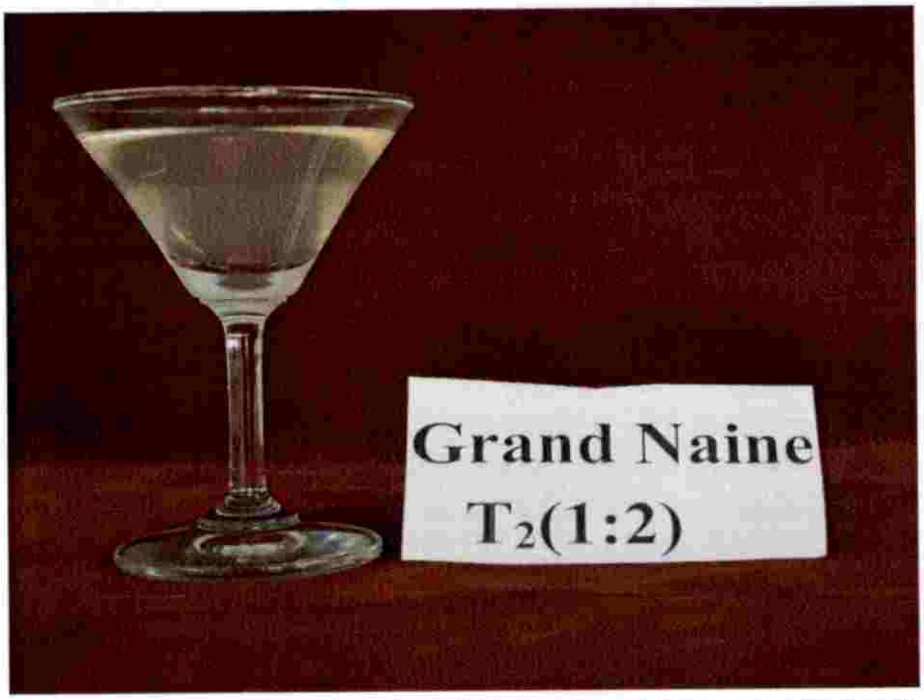
T17- Yangambi KM-5 1kg pulp+1ltr of water (1:1) +Pure strain of yeast (MTCC 4793)

T18- Yangambi KM-5 1kg pulp+2 ltr of water (1:2) +Pure strain of yeast (MTCC 4793)

T19- Palayankodan 1kg pulp+1ltr of water (1:1) +Pure strain of yeast (MTCC 4793)

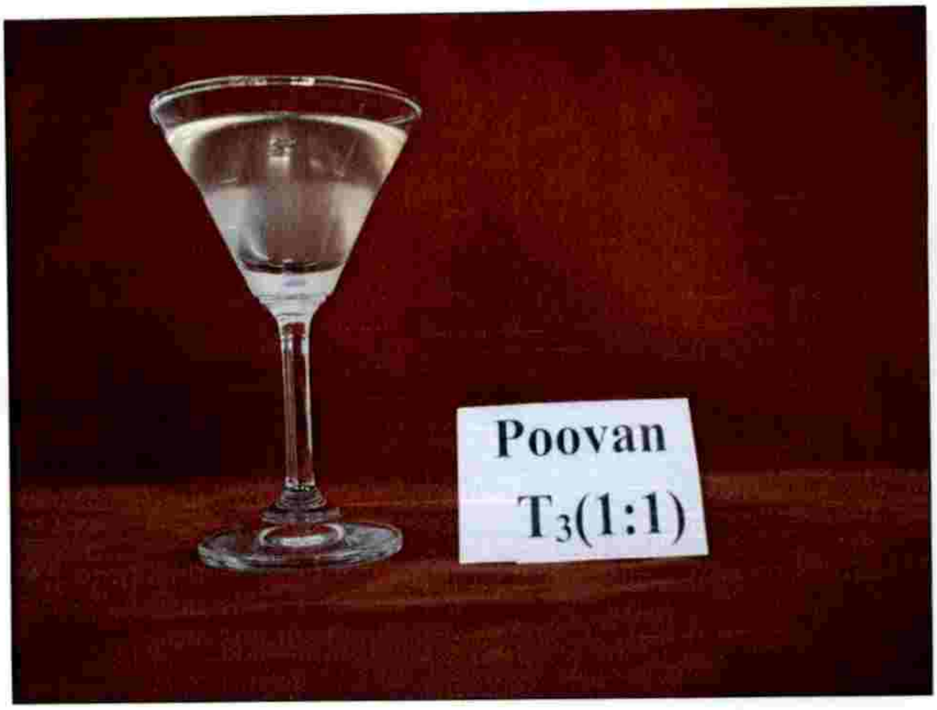
T20- Palayankodan 1kg pulp+2 ltr of water (1:2) +Pure strain of yeast (MTCC 4793)

T1-Grand Naine 1kg pulp+1ltr of water (1:1) +Baker's yeast



T2-Grand Naine 1kg pulp+2ltr of water (1:2) +Baker's yeast

Plate 3a: Wine from Grand Naine



T3- Poovan 1kg pulp+1ltr of water (1:1) +Baker's yeast

T4- Poovan 1kg pulp+2ltr of water (1:2) +Baker's yeast

Plate 3b: wine from Poovan

T5- Karpooravalli 1kg pulp+1ltr of water (1:1) +Baker's yeast

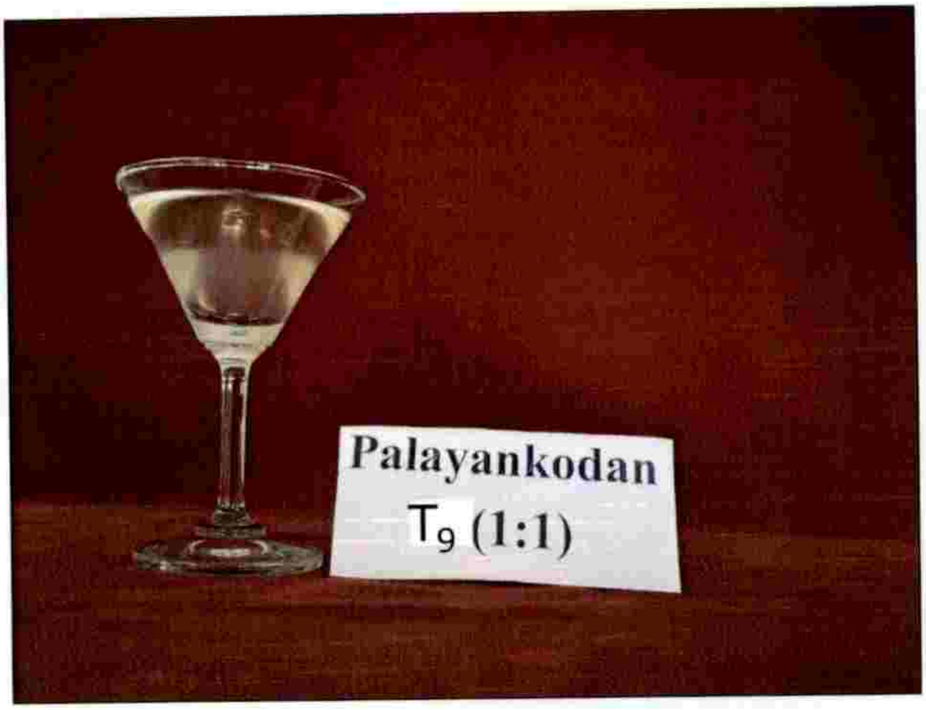
T6- Karpooravalli 1kg pulp+2ltr of water (1:2) +Baker's yeast

Plate 3c: Wine from Karpooravalli

T7- Yangambi KM-5 1kg pulp+1ltr of water (1:1) +Baker's yeast

T8- Yangambi KM-5 1kg pulp+2ltr of water (1:2) +Baker's yeast

Plate 3d: Wine from Yangambi KM-5



T9- Palyankodan 1kg pulp+1ltr of water (1:1) +Baker's yeast

T10- Palyankodan 1kg pulp+2ltr of water (1:2) +Baker's yeast

Plate 3e: Wine from Palayankodan

3.1.6 Nutritive and biochemical parameters

3.1.6.1 Wine yield

After the fermentation, wine was decanted leaving the dead yeast cells and other residues at the bottom of the fermenting jar. The wine yield was expressed as percentage of weight of wine to the initial weight of fermenting substrate including fruit pulp, sugar and water.

$$\text{Wine yield} = \frac{\text{Weight of wine obtained}}{\text{Initial weight of fermenting substrate}} \times 100$$

3.1.6.2 pH

Standard digital pH meter was used in determining the pH of banana wine

3.1.6.3 Total soluble solids (TSS)

Total soluble solids were found out using a digital refractometer (range 0-32^0) and expressed as degree brix (^{0} Brix).

3.1.6.4 Titratable acidity

A known weight of sample was mixed with distilled water and made upto a known volume. An aliquot of the filtered solution was titrated against 0.1N sodium hydroxide using phenolphthalein as indicator. The acidity was calculated using the formula given below and was expressed as percentage of malic acid (AOAC, 1998).

$$\text{Acidity} = \frac{\text{Normality x titre value x equivalent weight x volume made up}}{\text{Weight of sample x aliquot of sample x 1000}} \times 100$$

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3.1.6.5 Reducing sugars (%)

A known weight of wine sample was first neutralized with 1N NaOH by using phenolphthalein as an indicator and transferred to a 250 ml volumetric flask. About 100 ml of distilled water was added followed by 2 ml pre standardized 45 per cent neutral lead acetate for clarification. Excess lead acetate was neutralized by addition of 2 ml pre standardized 22 per cent potassium oxalate solution. The clarified solution was made up to the mark with distilled water. This was filtered through Whatman's No.1 filter paper. In the clarified filtrate, the reducing sugar was determined by titrating against standard Fehling's solution using methylene blue as an indicator (Ranganna, 1997). The quantity of reducing sugars was calculated by the formula given below.

$$\text{Reducing sugars (\%)} = \frac{\text{Fehling's Factor x dilution x 100}}{\text{Titre value x weight of sample}}$$

3.1.6.6 Non reducing sugars (%)

Non-reducing sugars was estimated by subtracting the amount of reducing sugars from the total sugars. The non-reducing sugars were calculated using the formula and expressed as percentage (AOAC, 1998).

Non-reducing sugars (%) = Total sugars (%) - Reducing sugars (%)

3.1.6.7 Total sugars (%)

50 ml of the filtrate used in the estimation of reducing sugars was taken into a 100ml volumetric flask and 5 ml of

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concentrated HCl was added for hydrolyzing the sample. Then the hydrolysed solution was neutralized with 20 per cent NaOH by using one or two drops of phenolphthalein. Diluted HCl was added till it became colourless. Finally, the volume was made upto 100ml and it was titrated against standard Fehlings solution using methylene blue as an indicator (Ranganna, 1997). The total sugars were calculated as given below.

$$\text{Total sugars (\%)} = \frac{\text{Fehling's factor x 250 x dilution}}{\text{Titre value x 50 x weight of sample}} \text{x100}$$

3.1.6.8 Ascorbic acid (mg 100 g^{-1})

Five ml of the sample was taken and extracted with four per cent oxalic acid. Ascorbic acid was estimated by using standard indicator dye 2, 6- dichlorophenol indophenol and expressed as mg 100g^{-1} of fruit (AOAC, 1998).

$$\text{Ascorbic acid (mg/100g)} = \frac{\text{Titre value x dye factor x volume made up x 100}}{\text{Weight of sample x aliquot of sample}}$$

3.1.6.9 Total phenols

Folin- Ciocalteau reagent was used in the estimation of phenols. A blue coloured complex (Molybdenum blue) is synthesized when phenols react with phosphomolybdic acid in alkaline medium (Asami *et al.,* 2003)

The wine sample (5ml) was added to 80 per cent ethanol and centrifuged continuously till it became colourless. The supernatant was collected and pooled. It was evaporated to dryness in hot water bath. Residue was dissolved in distilled water (5ml).

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Different aliquots of standards and extracted sample (0.5ml) were pipetted out into test tubes.

All test tubes including blank was made upto volume 3ml with distilled water. Folin- Ciocalteau reagent of 0.5 ml was added to all test tubes and allowed to stand for 3 minutes. 2ml of 20 per cent of sodium carbonate was added to all test tubes and mixed thoroughly and kept at room temperature for 60 minutes. Optical density value was measured in a spectrophotometer at 650nm. A standard curve was drawn by taking concentration on x-axis and absorbance on the y- axis and the concentration of phenols were estimated in the sample.

3.1.6.10 Alcohol content

Specific gravity of the fermenting must and specific gravity of wine were determined separately. The alcohol content of wine was calculated by the following formula (Berry, 1998)

$$\text{Alcohol by volume\% (ABV)} = \frac{\text{Original Specific Gravity - final Specific Gravity}}{7.36} \times 1000$$

3.1.6.11 Estimation of yeast population

Sabouraud's Dextrose Agar media was used for determination of yeast population using different dilution from 10^{-1} to 10^{-6}. One ml of each dilution was pipetted into a sterile Petridish using a micropipette. About 20 ml of the melted and cooled Sabouraud's Dextrose Agar (SDA) was poured into the Petridish and it was swirled. After solidification, it was kept for incubation at room temperature. Three Petridishes were kept as replicate for each sample. The Petriplates were incubated at room temperature for 4 to

5 days. The colonies developed were counted and expressed as cfu/ml of the sample (Agarwal and Hasija, 1986)

3.1.6.12 Energy

Energy value of wine was calculated by multiplying the protein, fat, and carbohydrate contents by factors of 4, 9, and 4 kcal/g, respectively.

Energy (kcal) = (Carbohydrate×4) + (Fat×9) + (Protein×4)

3.1.6.13 Economics

Cost of production of wine was calculated by working out the cost incurred on raw materials used and the labour charge for the wine preparation.

3.1.6.14 Sensory evaluation

Quality of banana wine was judged by a panel of judges of different age groups for appearance, colour, flavour, body, odour, taste, after taste and overall acceptability, based on a 9 point hedonic scale rating (Amerine *et al.*, 1965). A score of 5.5 and above was considered acceptable.

3.2 QUALITY EVALUATION OF WINE DURING AGEING/ STORAGE

Based on the organoleptic evaluation of different wines, the wine getting highest score from each variety of banana was selected for storage studies

3.2.1 Quality evaluation of wine during ageing

The selected wines were stored in china clay jar for two months and changes during ageing were studied. Observations were recorded at monthly intervals to note the changes in quality during ageing

Type of container – (china clay jar)

Design - CRD

Treatments -5

Replications - 4

3.2.1.1 Biochemical parameters

3.2.1.1.1 pH

pH was estimated as in 3.1.6.2

3.2.1.1.2 TSS

TSS was estimated as in 3.1.6.3

3.2.1.1.3 Titratable acidity

Titratable acidity was estimated as in 3.1.6.4

3.2.1.1.4 Total sugars

Total sugars were estimated as in 3.1.6.5

3.2.1.1.5 Reducing sugars

Reducing sugars were estimated as in 3.1.6.6

3.2.1.1.6 Non reducing sugars

Non reducing sugars were estimated as in 3.1.6.7

3.2.1.1.7 Ascorbic acid

Ascorbic acid was estimated as in 3.1.6.8

3.2.1.1.8 Total phenols

Total phenols were estimated as in 3.1.6.9

3.2.1.1.9 Alcohol content

Alcohol content was estimated as in 3.1.6.10

3.2.1.1.10 Flavour profile

GC-MS analysis was performed on a Trace 1300 gas chromatograph system equipped with 30m X 0.25mm ID with

SU

0.25μm film-thickness TG5MS fused silica capillary column. The 1μl of wine sample was injected. The detector and injector had temperatures 270 and 250 °C, respectively and the column oven temperature program was: 50 ° C for 2 min. followed by increment of 3 ° C/min up to 200 ° C held for 8 min., and then, with increment rate of 10 °C/min. up to 220 °C and held for 8 min at the same temperature. The carrier gas was helium, with a flow rate of 1.0ml/min. Trace 1300 Gas Chromatograph coupled to a TSQ 8000, Ion-trap mass spectra detector equipped with a fused-silica capillary column TG5MS with 30m x 0.25mm id, 0.25μm film-thickness was used for GC-MS analysis of volatile constituents. The ion trap, transfer line and ion source temperatures were maintained at 200 °C, 240 °C and 210 °C, respectively. Temperature was programmed as described earlier. Head-space volatiles were quantified as relative per-cent area in GC-MS chromatogram, and were identified by comparing retention index as determined using homologous series of n-alkanes (C_5 to C_{32}) as the standard (Wang *et al.,* 1994) and comparing the spectra available with spectral library NIST MS Search 2.0.

3.2.1.1.11 Sensory evaluation

Sensory evaluation was conducted as in 3.1.6.14

3.2.1.1.12 Estimation of yeast population

Yeast population was estimated as in 3.1.6.11

3.2.1.1.13 Estimation of bacterial population

Bacterial population was estimated using 10^{-5} dilution on nutrient agar medium. One ml of 10^{-5} dilution was pipetted into a sterile Petridish using a micropipette. About 20 ml of the melted and cooled Nutrient Agar (NA) media was poured into the Petridish and it was swirled. After solidification, it was kept for incubation at room temperature. Three Petridishes were kept as replicate for each sample. The Petriplates were incubated at room temperature for 48 hours. The colonies developed were counted and expressed as cfu/ml of sample.

3.2.1.1.14 Estimation of fungal population

Fungal population was estimated using 10^{-3} dilution on Martin Rose Bengal Agar medium. One ml of 10^{-3} dilution was pipetted into a sterile Petridish using a micropipette. About 20 ml of the melted and cooled Martin Rose Bengal Agar (MRBA) media was poured into the Petridish and it was swirled. After solidification, it was kept for incubation at room temperature. Three Petridishes were kept as replicate for each sample. The Petriplates were incubated at room temperature for 4 to 5 days. The colonies developed were counted and expressed as cfu/ml of the sample.

3.2.1.1.15 Estimation of *Lactobacillus* spp population

Lactobacillus population was estimated using 10^{-4} dilution on Lactobacillus MRS Agar medium. One ml of 10^{-4} dilution was pipetted into a sterile petridish using a micropipette. About 20 ml of the melted and Lactobacillus MRS Agar medium was poured into the Petridish and it was swirled. After solidification, it was kept for incubation at room temperature. Three Petridishes were kept as replicate for each sample. The Petriplates were incubated at room temperature for 48 hours. The colonies developed were counted and expressed as cfu/ml of sample.

3.2.2 Quality evaluation of wine during storage

After two of month's storage, wine was filled in glass bottles with crown cork, sealed, pasteurized at 82-88 °C for 2 minutes and stored under ambient conditions for three months.

Types of wine- 5

Types of containers – 2 (plain and amber coloured glass bottles)

Design – CRD

Treatments-10

Replications - 3

3.2.2.1 Biochemical parameters

3.2.2.1.1 pH

pH was estimated as in 3.1.6.2

3.2.2.1.2 TSS

TSS were estimated as in 3.1.6.3

3.2.2.1.3 Titratable acidity

Titratable acidity was estimated as in 3.1.6.4

3.2.2.1.4 Total sugars

Total sugars were estimated as in 3.1.6.5

3.2.2.1.5 Reducing sugars

Reducing sugars were estimated as in 3.1.6.6

3.2.2.1.6 Non reducing sugars

Non reducing sugars were estimated as in 3.1.6.7

3.2.2.1.7 Ascorbic acid

Ascorbic acid was estimated as in 3.1.6.8

3.2.2.1.8 Total phenols

Total phenols were estimated as in 3.1.6.9

3.2.2.1.9 Alcohol content

Alcohol content was estimated as in 3.1.6.10

3.2.2.1.10 Sensory evaluation

Sensory evaluation was estimated as in 3.1.6.11

3.2.2.1.11 Estimation of yeast population

Yeast population was conducted as in 3.1.6.14

3.2.2.1.12 Estimation of bacterial population

Bacterial population was estimated as in 3.2.1.1.13

3.2.2.1.13 Estimation of fungal population

Fungal population was estimated as in 3.2.1.1.14

3.2.2.1.14 Estimation of *Lactobacillus* spp population

Lactobacillus spp was estimated as in 3.2.1.1.15

Results

4. RESULTS

The results of the present investigation entitled "Process standardisation and quality evaluation of wine from banana (*Musa spp.*) is presented in this chapter under the following sections.

4.1 Evaluation of banana varieties for quality wine production

4.2 Quality evaluation of wine during storage/ageing

4.1 EVALUATION OF BANANA VARIETIES FOR QUALITY WINE PRODUCTION

The wine produced from various varieties of banana showed considerable variation in its biochemical parameters.

4.1.1 Biochemical characteristics of banana varieties

Banana varieties selected for wine making (Grand Naine, Poovan, Karpooravalli, Yangambi (KM-5) and Palayankodan) were evaluated for the biochemical characteristics (Table1). Among the varieties, highest total soluble solids (22.0 ^{0}Brix) was recorded in Yangambi (KM-5) and the lowest in Palayankodan (18 ^{0} Brix). The pH was highest in Palayankodan (4.72) and lowest in Grand Naine (4.12). Ascorbic acid content was highest in Poovan (2.81 mg 100g $^{-1}$) and lowest in Palayankodan (2.24 mg 100g $^{-1}$). The variety Karpooravalli had the highest titratable acidity (0.51%) and Grand Naine recorded the lowest (0.39%). Specific gravity was highest (1.062) in varieties like Karpooravalli, Grand Naine and Palayankodan and lowest (1.061) in Yangambi and Poovan. Moisture content was highest in Grand Naine (84.51%) and lowest (71.98%) in Karpooravalli. Grand Naine had the highest ash (8.65%) and protein content (7.62 %) whereas the lowest ash (5.36%) and protein (4.79%) content was recorded in Karpooravalli. The fat content was highest (1.36%) in Karpooravalli and lowest in Palayankodan (0.61%).

Table 1 Biochemical characteristics of banana varieties

	TSS (^{0} Brix)	pH	Ascorbic Acid (mg 100 g^{-1})	Titratable Acidity (%)	Specific Gravity	Moisture (%)	Ash (%)	Protein (%)	Fat (%)
Grand Naine	21.0	4.12	2.40	0.39	1.062	84.51	8.65	7.62	0.81
Poovan	20.0	4.71	2.81	0.45	1.061	82.97	6.18	6.76	1.13
Karpooravalli	19.0	4.23	2.54	0.51	1.062	71.98	5.36	4.79	1.36
Yangamby KM-5	22.0	4.33	2.30	0.49	1.061	74.21	7.51	6.52	1.12
Palayankodan	18.0	4.72	2.24	0.54	1.062	78.09	7.24	6.69	0.61

4.1.2 Nutritive and biochemical parameters of banana wine

4.1.2.1 Sensory evaluation

Sensory evaluation of banana wine from all varieties varied significantly (Table 2 and 3) Quality of wine prepared using Baker's yeast and pure wine yeast strain varied significantly in their organoleptic properties. Sensory evaluation of wine prepared using pure wine yeast revealed that this wine was not acceptable as all treatments had a score less than 5.5. Wine prepared using Baker's yeast with different ratios of pulp and water revealed that 1:2 ratio of pulp and water was better for varieties Grand Naine, Poovan, Yangambi (KM-5) and Palayankodan which had a score of 7.0,7.1,7.0 and 7.1 respectively, whereas 1:1 ratio was better for the wine from Karpooravalli, which had an overall acceptability score of 7.0. These five treatments were selected for ageing.

4.1.1.2 pH

The pH of wine from banana varieties ranged from 3.43 to 4.64 (Table 4). Wine from all varieties of banana prepared with pulp and water ratio of 1:1 had higher pH than the wine prepared with 1:2 ratio of pulp and water. Wine from Yangambi with pulp and water ratio of 1:1 had the highest pH (4.64) and the lowest (3.43) was in the wine from the variety Grand Naine with pulp and water ratio of 1:2

4.1.1.3 Total soluble solids (TSS)

The total soluble solids varied slightly among the different treatments (Table 5). The total soluble solids of the treatments ranged from 4.0 to 5.1 ^{0}Brix.Wine from all varieties of banana prepared with pulp and water ratio of 1:1 had higher total soluble solids than the wine prepared with 1:2 ratio of pulp and water. Wine from Grand Naine with pulp and water ratio of 1:1 had the highest total soluble solids (5.1^{0}Brix) and the lowest (4.0 ^{0}Brix) was in the wine from the variety Yangambi and Poovan with pulp and water ratio of 1:2.

Table 2 Effect of pulp: water ratio on organoleptic quality of banana wine using Baker's yeast

Treatments	Ratio of pulp and water	Appearance	Colour	Flavour	Odour	Body	Taste	After taste	Over all acceptability
T1	1:1	6.4	5.9	5.6	7.0	6.2	5.8	6.1	6.3
	1:2	7.2	6.7	6.3	6.4	6.9	6.0	6.1	7.0.
Kendal's W test		**0.544**	**0.129**	**0.296**	**0.18**	**0.5**	**0.18**	**0**	**0.357**
T2	1:1	6.4	5.8	6.0	6.8	6.2	6.1	5.9	6.5
	1:2	7.5	7.6	6.4	7.1	6.7	6.6	6.2	7.1
Kendal's W test		**0.7**	**1.0**	**0.18**	**0.18**	**0.4**	**0.5**	**0.18**	**0.6**
T3	1:1	6.9	7.5	6.9	7.2	6.8	7.0	6.8	7.0
	1:2	7.0	7.2	6.0	6.8	6.4	6.1	6.2	6.5
Kendal's W test		**0.02**	**0.3**	**0.544**	**0.3**	**0.129**	**0.64**	**0.4**	**0.4**
T4	1:1	6.5	6.6	6.6	7.0	6.7	5.8	6.1	6.3
	1:2	7.4	7.3	7.3	6.4	7.4	6.0	6.1	7.0
Kendal's W test		**0.7**	**0.6**	**0.6**	**0.18**	**0.6**	**0.18**	**0**	**0.357**
T5	1:1	6.6	6.5	6.4	6.6	6.6	6.3	6.4	6.6
	1:2	7.0	6.7	7.0	6.7	6.8	7.0	6.4	7.1
Kendal's W test		**0.18**	**0.033**	**0.45**	**0.1**	**0.67**	**0.357**	**0.014**	**0.2**

T1-Grand Naine banana wine (Baker's yeast)

T2-Poovan banana wine (Baker's yeast)

T3-Karpooravalli banana wine (Baker's yeast)

T4-Yangambi (KM-5) banana wine (Baker's yeast

T5 –Palayankodan (Baker's yeast)

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Table 3 Effect of pulp: water ratio on organoleptic quality of banana wine using pure strain (MTCC 4793)

Treatments	Ratio of pulp and water	Appearance	Colour	Flavour	Odour	Body	Taste	After taste	Over all acceptability
T6	1:1	5.4	6.1	4.1	4.0	4.1	3.6	3.5	3.5
	1:2	5.6	5.7	4.1	3.9	4.0	3.5	3.5	3.3
Kendal's W test		**0.067**	**0.225**	**0.02**	**0**	**0.014**	**0.014**	**0**	**0.067**
T7	1:1	5.4	5.9	3.7	3.4	4.0	3.4	2.9	2.9
	1:2	5.4	5.7	3.5	3.5	3.8	3.6	3.0	3.4
Kendal's W test		**0.02**	**0.067**	**0.1**	**0.02**	**0.02**	**0.067**	**0.033**	**0.139**
T8	1:1	5.2	5.8	3.7	3.5	3.9	3.1	2.8	2.9
	1:2	5.5	5.9	3.6	3.4	3.6	3.4	2.7	3.2
Kendal's W test		**0.129**	**0.014**	**0.033**	**0.02**	**0.129**	**0.18**	**0.033**	**0.1**
T9	1:1	5.5	5.6	3.7	3.0	3.7	3.6	3.2	3.5
	1:2	5.1	5.8	3.6	3.0	3.5	3.4	3.4	3.3
Kendal's W test		**0.267**	**0.067**	**0.02**	**0**	**0.067**	**0.067**	**0**	**0.067**
T10	1:1	5.2	5.7	3.7	3.6	3.7	3.0	3.4	3.2
	1:2	5.5	5.4	3.5	3.5	3.6	3.1	3.3	3.1
Kendal's W test		**0.129**	**0.220**	**0.067**	**0.014**	**0.02**	**0.014**	**0**	**0.014**

T1-Grand Naine banana wine (Pure strain)

T2-Poovan banana wine (Pure strain)

T3-Karpooravalli banana wine (Pure strain)

T4-Yangambi (KM-5) banana wine (Pure strain)

T5 –Palayankodan (Pure strain)

Table 4 Effect of pulp: water ratio on pH of banana wine

	Ratio of pulp and water		
TREATMENTS	**1:1**	**1:2**	**Mean B**
T1 (Grand Naine)	3.83	3.43	3.63
T2 (Poovan)	4.14	3.65	3.89
T3 (Karpooravalli)	3.80	3.71	3.76
T4 (Yangambi (KM-5)	4.64	3.55	4.09
T5 (Palayankodan)	3.85	3.77	3.81
Mean A	4.05	3.62	
Factors	**C.D.**	**SE(m)**	**F cal**
Factor(A)	0.073	0.025	154.64**
Factor(B)	0.115	0.039	19.886**
Factor(A X B)	0.163	0.055	27.889**

**significant at 1%

Table 5 Effect of pulp: water ratio on TSS (^{0}Brix) of banana wine

	Ratio of pulp and water		
TREATMENTS	**1:1**	**1:2**	**Mean B**
T1 (Grand Naine)	5.1	4.2	4.65
T2 (Poovan)	4.1	4.0	4.05
T3 (Karpooravalli)	5.0	4.2	4.60
T4 (Yangambi (KM-5)	4.3	4.0	4.15
T5 (Palayankodan)	4.2	4.1	4.15
Mean A	4.5	4.1	
Factors	**C.D.**	**SE(m)**	**F cal**
Factor(A)	0.077	0.026	108.303**
Factor(B)	0.121	0.041	50.55**
Factor(A X B)	0.172	0.058	32.548**

**significant at 1%

4.1.1.4 Titratable acidity (%)

The titratable acidity of the different treatments ranged from 0.80 to 1.37 % (Table 6). Wine from all varieties of banana prepared with pulp and water ratio of 1:1 had higher titratable acidity than the wine prepared with 1:2 ratio of pulp and water. Wine from Palayankodan with pulp and water ratio of 1:1 had the highest titratable acidity (1.37 %) and the lowest (0.80%) was in the wine from the variety Poovan with pulp and water ratio of 1:2.

4.1.1.5 Reducing sugars (%)

Reducing sugars could not be detected in any of the wine prepared from the various varieties of banana. (Table 7)

4.1.1.6 Non reducing sugars (%)

Non reducing sugars could not be detected in any of the wine prepared from the various varieties of banana. (Table 7)

4.1.1.7 Total sugars (%)

Total sugars could not be detected in any of the wine prepared from the various varieties of banana. (Table 7)

4.1.1.8 Ascorbic acid (mg 100g^{-1})

The ascorbic acid content of the treatments ranged from 1.64 to 2.28 mg 100 g^{-1} (Table 8). Wine from all varieties of banana prepared with pulp and water ratio of 1:1 had higher ascorbic acid than the wine prepared with 1:2 ratio of pulp and water. Wine from Poovan with pulp and water ratio of 1:1 had the highest ascorbic acid (2.28 mg 100g $^{-1}$) and the lowest (1.64 mg 100g $^{-1}$) was in the wine from the variety Karpooravalli with pulp and water ratio of 1:2.

Table 6 Effect of pulp: water ratio on titratable acidity (%) of banana wine

	Ratio of pulp and water		
TREATMENTS	**1:1**	**1:2**	**Mean B**
T1 (Grand Naine)	1.21	1.14	1.17
T2 (Poovan)	0.81	0.80	0.80
T3 (Karpooravalli)	1.00	0.85	0.92
T4 (Yangambi (KM-5)	1.34	0.87	1.10
T5 (Palayankodan)	1.37	0.92	1.14
Mean A	1.14	0.91	
Factors	**C.D.**	**SE(m)**	**F cal**
Factor(A)	0.065	0.031	55.874**
Factor(B)	0.103	0.049	21.36**
Factor(A X B)	0.145	0.069	9.886**

**significant at 1%

Table 7 Effect of pulp: water ratio on reducing sugars, non-reducing sugars and total sugars (%)of banana wine

	Reducing sugars		Non-reducing sugars		Total sugars	
	Ratio of pulp and water		Ratio of pulp and water		Ratio of pulp and water	
TREATMENTS	**1:1**	**1:2**	**1:1**	**1:2**	**1:1**	**1:2**
T1 (Grand Naine)	ND	ND	ND	ND	ND	ND
T2 (Poovan)	ND	ND	ND	ND	ND	ND
T3 (Karpooravalli)	ND	ND	ND	ND	ND	ND
T4 (Yangambi (KM-5)	ND	ND	ND	ND	ND	ND
T5 (Palayankodan)	ND	ND	ND	ND	ND	ND

Table 8 Effect of pulp: water ratio on ascorbic acid (mg 100 g^{-1}) content of banana wine

	Ratio of pulp and water		
TREATMENTS	**1:1**	**1:2**	**Mean B**
T1 (Grand Naine)	2.10	1.71	1.90
T2 (Poovan)	2.28	2.18	2.23
T3 (Karpooravalli)	2.17	1.64	1.90
T4 (Yangambi (KM-5)	2.00	1.80	1.90
T5 (Palayankodan)	2.09	1.90	1.99
Mean A	2.12	1.84	
Factors	**C.D.**	**SE(m)**	**F cal**
Factor(A)	0.035	0.012	282.249**
Factor(B)	0.056	0.019	55.944**
Factor(A X B)	0.079	0.027	21.174**

**significant at 1%

4.1.1.9 Total phenols (mg $100g^{-1}$)

Total phenol content of all treatments varied significantly (Table 9). The phenols of wine from banana varieties ranged from 59 to 85 mg 100 g^{-1}. Wine from all varieties of banana prepared with pulp and water ratio of 1:1 had higher total phenols than the wine prepared with 1:2 ratio of pulp and water. Wine from Yangambi with pulp and water ratio of 1:1 had the highest total phenols (85 mg 100g $^{-1}$) and the lowest (59.6 mg 100g $^{-1}$) was in the wine from the variety Poovan with pulp and water ratio of 1:2.

4.1.1.10 Alcohol content (%)

The alcohol content of wine from banana varieties ranged from 8.25 to 9.58% (Table 10). Wine from all varieties banana prepared with pulp and water ratio of 1:2 had higher alcohol content than the wine prepared with 1:1 ratio of pulp and water. Wine from Karpooravalli with pulp and water ratio of 1:2 had the highest alcohol content (9.58 %) and the lowest (8.25 %) was in the wine from the variety Grand Naine with pulp and water ratio of 1:1.

4.1.1.11 Yeast population (cfu/ml)

The yeast population wine from all samples were enumerated (Table 11) Wine from all varieties did not differ significantly in the yeast population and it ranged from 11 to 12×10^6 cfu/ml. Wine from all varieties of banana prepared with pulp and water ratio of 1:1 had higher yeast population content than the wine prepared with 1:2 ratio of pulp and water. Wines from Poovan and Yangambi with pulp and water ratio of 1:1 had the highest yeast population (12.0×10^6 cfu/ml) and the lowest (11.0×10^6 cfu/ml) was in the wine from the varieties of Grand Naine, Karpooravalli and Yangambi with pulp and water ratio of 1:2.

4.1.1.12 Energy (kcal)

The energy value varied significantly among the different treatments (Table 12). The energy value of wine from banana varieties ranged from 21.70 to 29.84 kcal. Wine from banana varieties prepared with pulp and water ratio of 1:1 had higher energy value than the wine prepared with 1:2 ratio of pulp and water. Wine from Palayankodan with pulp and water ratio of 1:1 had the highest energy value (29.84 kcal) and the lowest (21.70 kcal) was in the wine from the variety Yangambi with pulp and water ratio of 1:2.

4.1.1.13 Wine yield

Wine yield varied significantly among the treatments (Table 13) which ranged from 40 to 79%. Wine from all varieties of banana prepared with pulp and water ratio of 1:2 had higher wine yield than the wine prepared with 1:1 ratio of pulp and water. Wine from Grand Naine with pulp and water ratio of 1:2 had the highest wine yield (79.0 %) and the lowest (40.0 %) was in the wine from the variety Poovan with pulp and water ratio of 1:1.

4.1.1.14 Economics

Cost of production of banana wine is presented in the Table 14. It was calculated by taking into account the cost of raw materials and inputs required in wine making. The cost of production of 1 litre of wine was 129.6 and the benefit: cost (B: C) ratio for the same was 2.08:1 .

Amount of wine = 1 liter

Total number of bottles = 1(1000ml/bottle)

Total income = Price of 1 l of wine

= 400 (Rs.)

Total revenue =Income – Cost of preparation

=400– 129.6

= 270.4 (Rs.)

Benefit: Cost ratio = 2.08: 1

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Table 9 Effect of pulp: water ratio on total phenols (mg 100 g^{-1}) of banana wine

	Ratio of pulp and water		
TREATMENTS	**1:1**	**1:2**	**Mean B**
T1 (Grand Naine)	65.0	60.0	62.5
T2 (Poovan)	64.0	59.6	61.8
T3 (Karpooravalli)	75.0	65.0	70.0
T4 (Yangambi (KM-5)	85.0	80.0	82.5
T5 (Palayankodan)	64.0	61.0	62.5
Mean A	70.6	65.1	
Factors	**C.D.**	**SE(m)**	**F cal**
Factor(A)	0.817	0.275	79.529**
Factor(B)	1.291	0.435	413.853**
Factor(A X B)	1.826	0.615	38.941**

****significant at 1%**

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Table 10 Effect of pulp: water ratio on alcohol content (%) of banana wine

	Ratio of pulp and water		
TREATMENTS	**1:1**	**1:2**	**Mean B**
T1 (Grand Naine)	8.25	8.28	8.26
T2 (Poovan)	8.87	9.31	9.09
T3 (Karpooravalli)	8.88	9.58	9.23
T4 (Yangambi (KM-5)	9.02	9.44	9.23
T5 (Palayankodan)	9.29	9.35	9.32
Mean A	8.86	9.19	
Factors	**C.D.**	**SE(m)**	**F cal**
Factor(A)	0.083	0.028	70.29**
Factor(B)	0.131	0.044	96.86**
Factor(A X B)	0.186	0.062	10.08**

**significant at 1%

Table 11 Population of yeast (cfu/ml) in banana wine (10^6)

	Ratio of pulp and water		
TREATMENTS	**1:1**	**1:2**	**Mean B**
T1 (Grand Naine)	11.2	11.0	11.1
T2 (Poovan)	12.0	12.0	12.0
T3 (Karpooravalli)	11.6	11.0	11.3
T4 (Yangambi (KM-5)	12.0	11.0	11.5
T5 (Palayankodan)	11.4	12.0	11.7
Mean A	11.6	11.4	
Factors	**C.D.**	**SE(m)**	**F cal**
Factor(A)	N/A	0.216	0.615^{NS}
Factor(B)	N/A	0.342	1.041^{NS}
Factor(A X B)	N/A	0.484	0.785^{NS}

NS-Non significant

Table 12 Energy value (kcal/g) of wine from banana varieties

	Ratio of pulp and water		
TREATMENTS	**1:1**	**1:2**	**Mean B**
T1 (Grand Naine)	24.71	24.62	24.66
T2 (Poovan)	25.91	22.12	24.01
T3 (Karpooravalli)	21.92	21.91	21.91
T4 (Yangambi (KM-5)	22.73	21.70	22.21
T5 (Palayankodan)	29.84	28.24	29.04
Mean A	25.02	23.72	
Factors	**C.D.**	**SE(m)**	**F cal**
Factor(A)	0.685	0.231	15.989**
Factor(B)	1.084	0.365	61.45**
Factor(A X B)	1.532	0.516	4.487**

**significant at 1%

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Table 13 Effect of pulp: water ratio on wine yield (%) of banana wine

	Ratio of pulp and water		
TREATMENTS	**1:1**	**1:2**	**Mean B**
T1 (Grand Naine)	70.0	79.0	74.5
T2 (Poovan)	40.0	51.0	45.5
T3 (Karpooravalli)	47.5	63.0	55.25
T4 (Yangambi (KM-5)	40.5	63.0	51.75
T5 (Palayankodan)	47.5	63.0	55.25
Mean A	49.1	63.8	
Factors	**C.D.**	**SE(m)**	**F cal**
Factor(A)	0.675	0.227	314.419**
Factor(B)	1.068	0.359	910.984**
Factor(A X B)	1.51	0.508	496.597**

**significant at 1%

Table 14 Cost of production of wine

Ingredients	Quantity	Approximate cost (Rs.)
Banana*	1000 (g)	20-35
Sugar	300 (g)	12.6
Baker's yeast	5(g)	1.45
Clarifying agent	1 egg white	5
Cost of sealing and labeling	1 bottle	2
Cost of bottle	1 bottle	5
Preservative(KMS)	0.05(g)	0.05
Labour Charges	30 minutes	37.5
Other cost including fuel charge	30 minutes	14.2
Banana wine	**1 litre**	**129-144**

4.2 QUALITY EVALUATION OF WINE DURING AGEING

4.2.1 Quality evaluation of wine during ageing

The selected wines were stored in china clay jar for two months and changes during ageing were studied. Observations were recorded at monthly intervals to note the changes in quality of wine during ageing.

4.2.1.1 Biochemical parameters

4.2.1.2.1 pH

The pH of wine showed an increasing trend during the ageing period (Table 15). After 30 days of ageing, wine from Karpooravalli recorded the highest (3.83) pH and the lowest was recorded in wine from the variety Grand Naine (3.64). The wine prepared from Karpooravalli recorded the highest pH (3.85) and the lowest (3.69) was noticed in wine from Yangambi, after 60 days of ageing.

4.2.1.2.2 Total soluble solids (^{0} Brix)

Total soluble solids of banana wine decreased throughout the ageing period (Table 15). The wine from Karpooravalli recorded the highest TSS (4.72 ^{0}Brix) and the lowest (3.87 ^{0}Brix) was recorded in the wine from Poovan on 30th day of ageing. Similar trend followed after 60 days of ageing where in highest TSS (4.52 ^{0}Brix) was noticed in wine from Karpooravalli and the lowest (3.65 ^{0}Brix) in wine prepared from Poovan.

4.2.1.2.3 Titratable acidity (%)

Titratable acidity of banana wine decreased throughout the ageing period (Table 15). The titratable acidity was highest in wine from Grand Naine (1.12%) and the lowest was recorded in wine produced from Poovan (0.76 %) after 30 days of ageing. After 60 days of ageing, wine from Grand Naine recorded the highest titratable acidity (1.00%) and the lowest was recorded in wine from Poovan (0.72 %).

Plate 4: Wine kept for ageing

Table 15. Effect of ageing on pH, total soluble solids(TSS) and titratable acidity of banana wine

Treatments	pH			Total soluble solids (° Brix)			Titratable acidity (%)		
	Initial	**30 DAS**	**60 DAS**	**Initial**	**30 DAS**	**60 DAS**	**Initial**	**30 DAS**	**60 DAS**
T1	3.43	3.64	3.73	4.2	4.0	3.8	1.21	1.12	1.00
T2	3.65	3.77	3.80	4.0	3.8	3.6	0.80	0.76	0.72
T3	3.80	3.83	3.85	5.0	4.7	4.5	1.00	0.92	0.80
T4	3.55	3.65	3.69	4.0	3.9	3.8	0.87	0.83	0.70
T5	3.77	3.80	3.82	4.2	4.0	3.8	0.92	0.86	0.82
CD		0.053	0.036		0.120	0.115		0.014	0.093

DAS: Days after storage

T1- Grand Naine banana wine (1:2 with pulp and water)

T2-Poovan banana wine (1:2 with pulp and water)

T3-Karpooravalli banana wine (1:1 with pulp and water)

T4-Yangambi (KM-5) banana wine (1:2 with pulp and water)

T5 –Palayankodan (control)

4.2.1.2.3 Reducing sugars (%)

Reducing sugars could not be detected in any of the wine samples (Table 16).

4.2.1.2.4 Non reducing sugars (%)

Non reducing sugars could not be detected in any of the wine samples (Table 16).

4.2.1.2.5 Total sugars (%)

Total sugars could not be detected in any of the wine samples (Table16).

4.2.1.2.6 Ascorbic acid (mg $100g^{-1}$)

The ascorbic acid content of banana wine showed a decreasing trend during ageing period (Table 17). After 30 days of ageing, wine from Poovan recorded the highest (1.99 mg $100g^{-1}$) ascorbic acid content and the lowest was recorded in wine from Grand Naine (1.65 mg $100g^{-1}$). The wine produced from Karpooravalli recorded the highest ascorbic acid (1.90mg $100g^{-1}$) and the lowest was noticed in wine from Yangambi and Grand Naine varieties (1.60 mg $100g^{-1}$), after 60 days of ageing.

4.2.1.2.6 Total phenols (mg $100g^{-1}$)

Total phenols of banana wine decreased throughout the ageing period (Table 17). The wine prepared from Yangambi recorded the highest (73.25 mg $100g^{-1}$) phenol content and the lowest (52.00 mg $100g^{-1}$) was recorded in wine from Grand Naine, after 30 days of ageing. Similar trend followed after 60 days of ageing, where in highest phenols (56.25 mg $100g^{-1}$) was noticed in wine from Yangambi and the lowest (40.50 mg $100g^{-1}$) was in wine from Grand Naine.

4.2.1.2.7 Alcohol (%)

Alcohol content of wine prepared from all varieties of banana increased throughout the ageing period (Table 17). Alcohol content was highest in wine prepared from Yangambi (9.56%) and the lowest was recorded in wine from Grand Naine (8.33 %), after 30 days of ageing. After 60 days of ageing, highest alcohol content (9.64%) was noticed in wine from Palayankodan and the lowest alcohol content was recorded in wine from Grand Naine (8.40 %).

Table 16 Effect of ageing on reducing sugars, non reducing sugars and total sugars of banana wine

Treatments	Reducing sugars (%)			Non-reducing sugars (%)			Total sugars (%)		
	Initial	30 DAS	60 DAS	Initial	30 DAS	60 DAS	Initial	30 DAS	60 DAS
T1	ND	ND	ND	ND	ND	ND	ND	ND	ND
T2	ND	ND	ND	ND	ND	ND	ND	ND	ND
T3	ND	ND	ND	ND	ND	ND	ND	ND	ND
T4	ND	ND	ND	ND	ND	ND	ND	ND	ND
T5	ND	ND	ND	ND	ND	ND	ND	ND	ND
CD	-	-	-	-	-	-	-	-	-

DAS: Days after storage

ND- Not detected

T1- Grand Naine banana wine (1:2 with pulp and water)

T2-Poovan banana wine (1:2 with pulp and water)

T3-Karpooravalli banana wine (1:1 with pulp and water)

T4-Yangambi (KM-5) banana wine (1:2 with pulp and water)

T5 –Palayankodan (control)

Table 17 Effect of ageing on ascorbic acid, phenol and alcohol content of banana wine

Treatments	Ascorbic acid (mg $100g^{-1}$)			Phenols (mg $100g^{-1}$)			Alcohol (%)		
	Initial	**30 DAS**	**60 DAS**	**Initial**	**30 DAS**	**60 DAS**	**Initial**	**30 DAS**	**60 DAS**
T1	1.71	1.65	1.60	60.00	52.00	40.50	8.28	8.33	8.40
T2	2.18	1.99	1.91	59.66	53.50	44.25	9.31	9.45	9.47
T3	2.17	1.98	1.90	75.00	66.37	41.37	8.83	9.28	9.36
T4	1.80	1.66	1.60	85.00	73.25	56.25	9.44	9.56	9.57
T5	1.90	1.74	1.68	61.00	52.50	42.25	9.29	9.52	9.64
CD		0.023	0.015		1.943	1.316		0.051	0.087

DAS: Days after storage

T1- Grand Naine banana wine (1:2 with pulp and water)

T2-Poovan banana wine (1:2 with pulp and water)

T3-Karpooravalli banana wine (1:1 with pulp and water)

T4-Yangambi (KM-5) banana wine (1:2 with pulp and water)

T5 –Palayankodan (control)

4.2.1.2.8 Flavour profile

GCMSMS analysis was carried out for the wine produced from different banana varieties to uncover the flavor profile (Table 18). The banana wine of different varieties differed from each other with respect to the constituents present. The major compounds in banana wine from the different varieties were ethanol, ethyl hydrogen succinate and glycerin. However, wine from Grand Naine contained a distinctive compound, methyl tartronic acid. The wine from Poovan also had compounds such as ethanol, ethyl hydrogen succinate, glycerin, phenyl ethyl alcohol and was distinctive from wine of the other varieties owing to the existence of a unique compound 1-Butanol-3-methyl. The wine produced from Karpooravalli contained a unique compound 1-Deoxy-d-arabitol in addition to ethanol, ethyl hydrogen succinate, glycerin and phenyl ethyl alcohol. Similar to the wine from the variety Grand Naine, the wine produced from Yangambi also contained methyl tratronic acid in addition to other compounds like ethanol, ethyl hydrogen succinate, glycerin and phenyl ethyl alcohol. The wine made from Palayankodan also had compounds such as ethanol, ethyl hydrogen succinate, glycerin, phenyl ethyl alcohol and was distinctive from wine of the other varieties owing to the existence of a special compound 3(p Hydroxyphenyl)1propanol.

4.2.1.2.9 Sensory evaluation

Organoleptic evaluation of wine was done during monthly interval of ageing (Table 21 and 22). After 30 days of ageing, wine prepared from Poovan had the highest overall acceptability score (7.6) and the lowest was found in wine from Yangambi (5.6), whereas after the completion of ageing, wine produced from Poovan had the highest overall acceptability score (7.6) and the lowest score

(5.9) was recorded in wine produced from the varieties Karpooravalli and Yangambi.

Table 18. Flavour compounds in banana wines (GCMSMS analysis)

		Treatments(wine)				
Compounds	**Aroma descriptor**	**Grand Naine**	**Poovan**	**Karpooravalli**	**Yangambi KM-5**	**Palayankodan**
Ethanol	alcohol	+	+	+	+	+
Methyltartronic acid	unpleasant smell	+	-	-	+	-
Ethyl hydrogen succinate	faint, pleasant odour	+	+	+	+	+
Glycerin	odourless	+	+	+	+	+
Phenyl ethyl Alcohol	floral	-	+	+	+	+
1-Deoxy-d-arabitol	unknown	-	-	+	-	-
1-Butanol-3-methyl	alcohol	-	+	-	-	-
3(p Hydroxyphenyl)1propanol	unknown	-	-	-	-	+

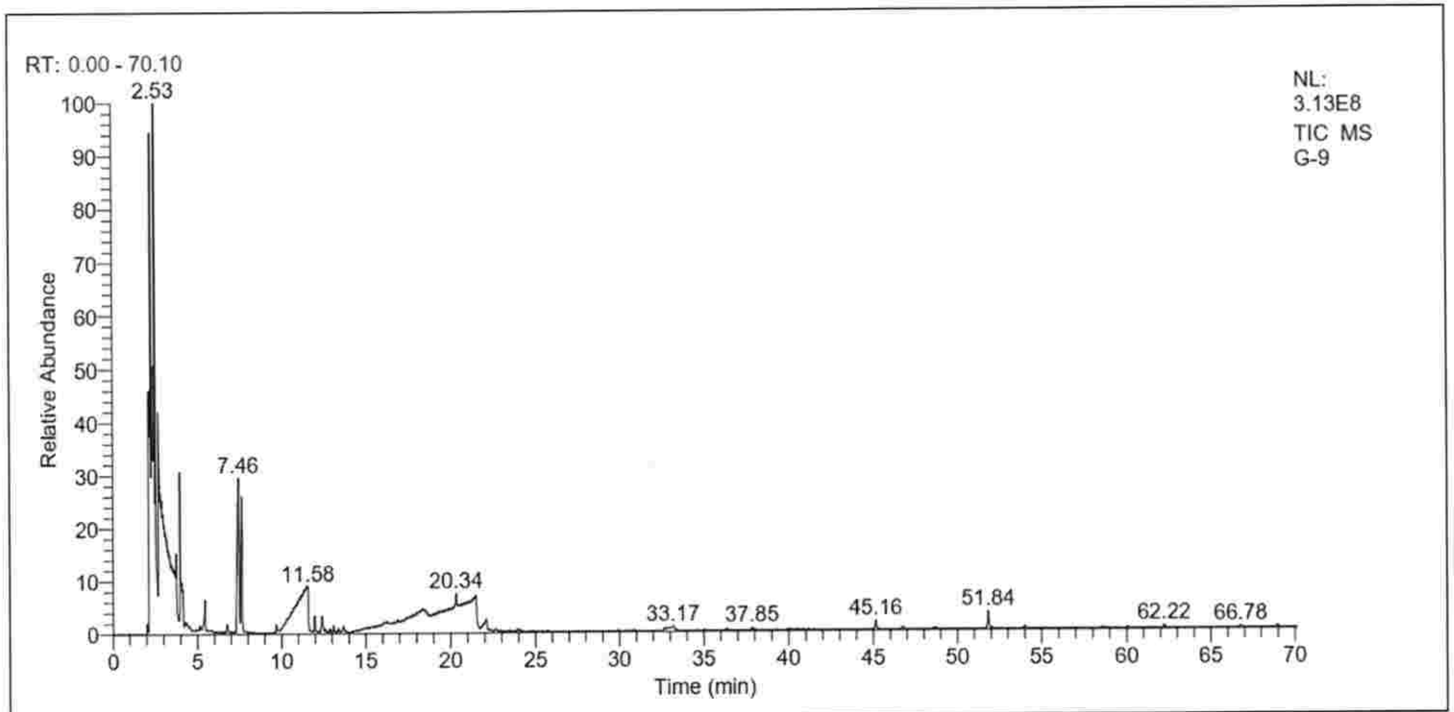

Figure 1: Flavour profile of GCMSMS analysis of wine from banana cv.Grand Naine

Compounds detected during GCMSMS analysis of Grand Naine wine

1. Ethanol
2. Methyltartronic acid
3. Ethyl hydrogen succinate
4. Glycerin

Data File: Grand Naine

Injection Volume (µl): 1.00

Run Time (min): 70.02

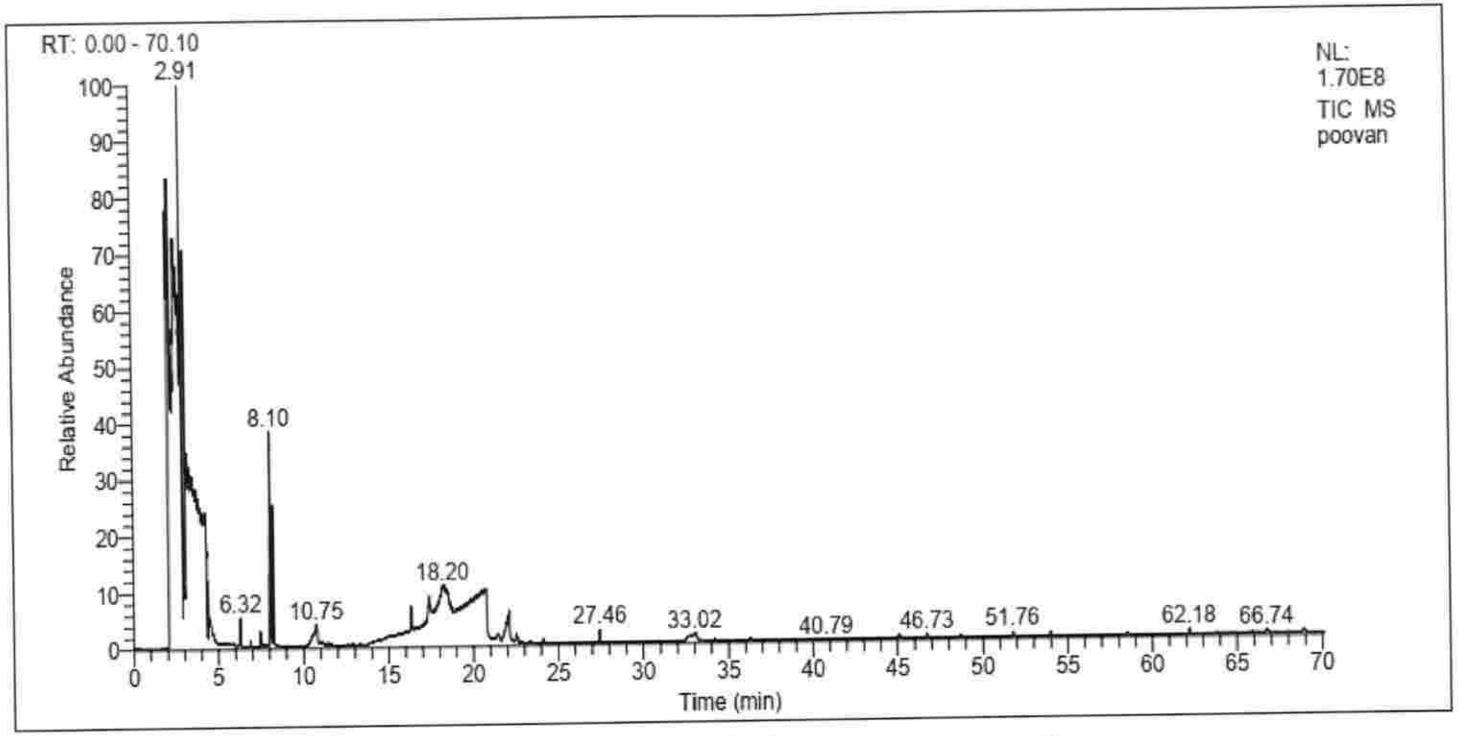

Figure 2: Flavour profile of GCMSMS analysis of wine from banana cv.Poovan

Compounds detected during GCMSMS analysis of Poovan wine

1. Ethanol
2. Phenyl ethyl Alcohol
3. 1-Butanol-3-methyl
4. Ethyl hydrogen succinate
5. Glycerin

Data File: Poovan
Injection Volume (µl):1.00
Run Time (min):70.02

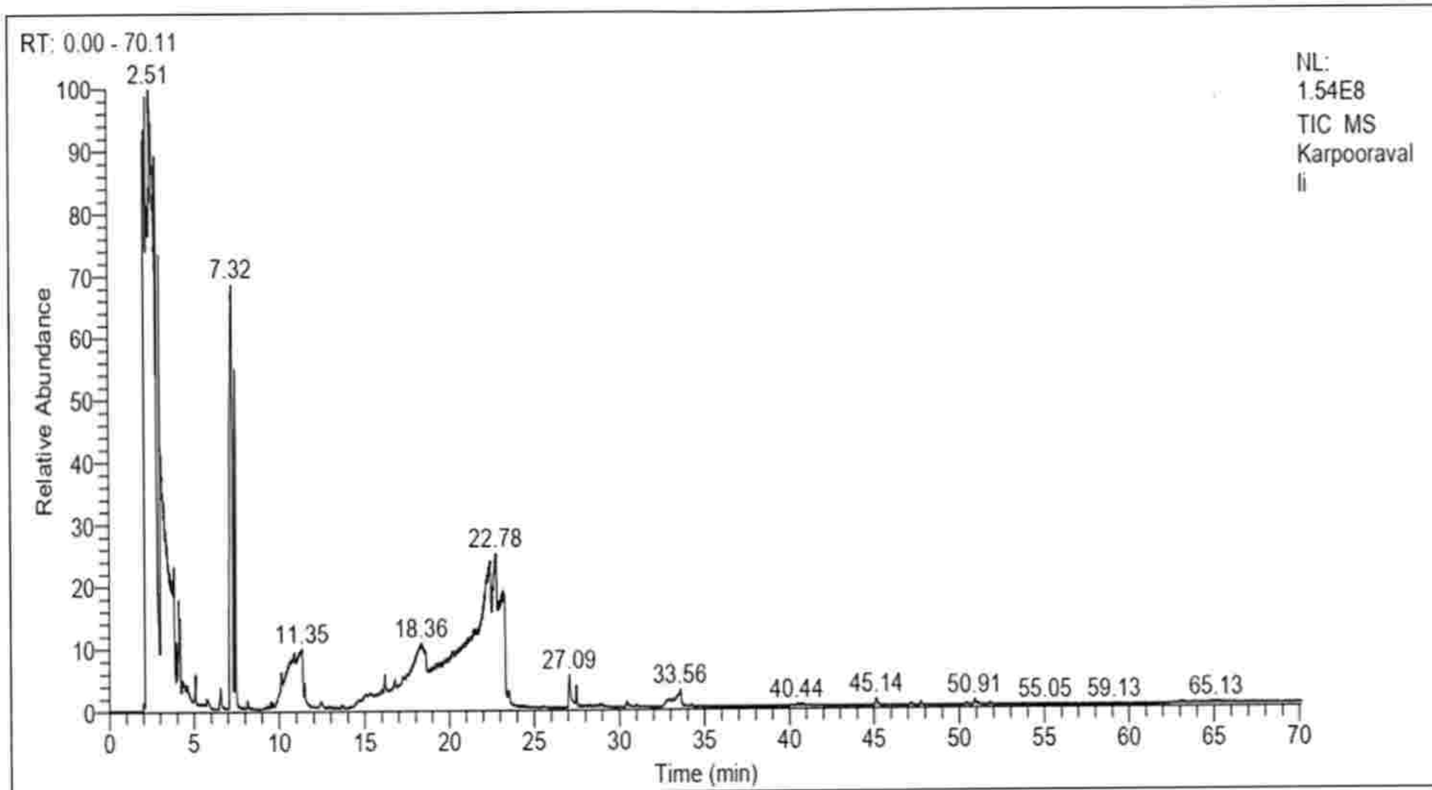

Figure 3: Flavour profile of GCMSMS analysis of wine from banana cv.Karpooravalli

Compounds detected during GCMSMS analysis of Karpooravalli wine

1. Ethanol
2. Phenyl ethyl Alcohol
3. 1-Deoxy-d-arabitol
4. Ethyl hydrogen succinate
5. Glycerin

Data File: Karpooravalli

Injection Volume (µl):1.00

Run Time (min): 70.02

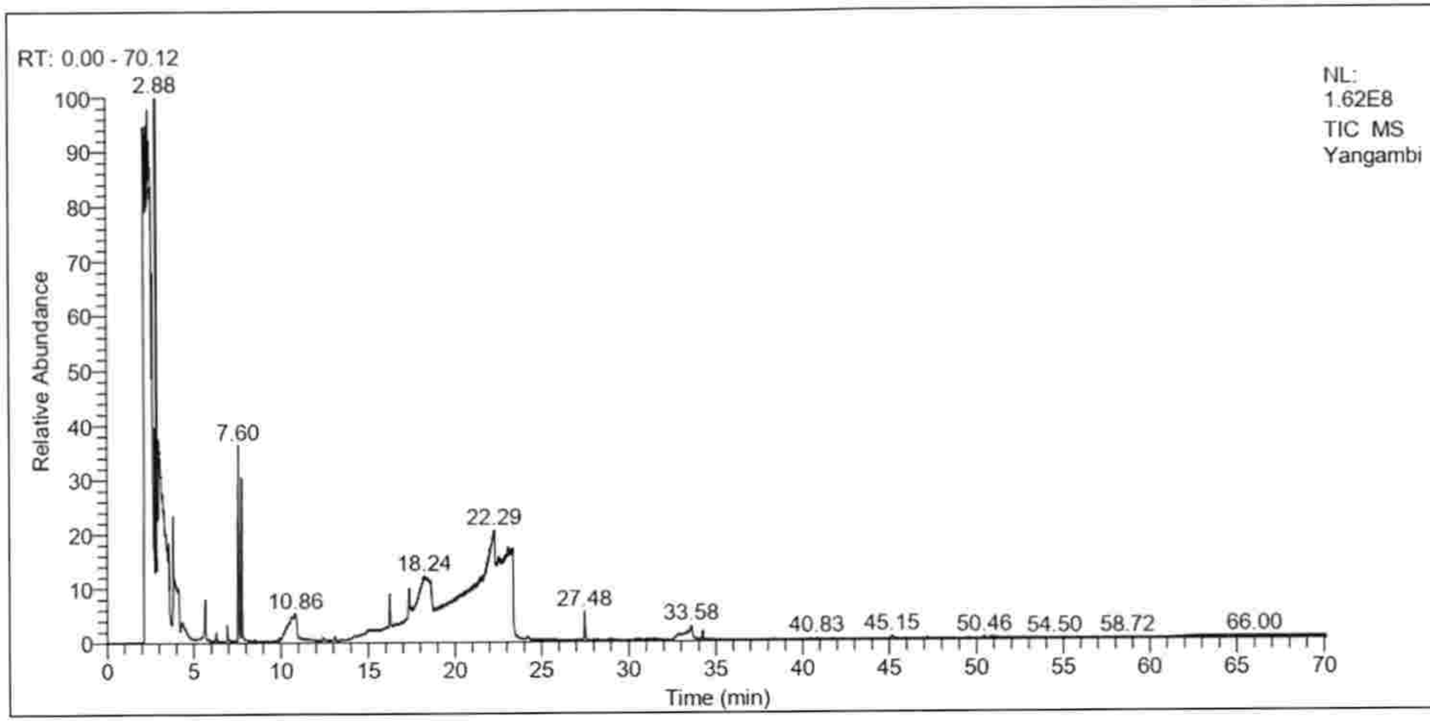

Figure 4: Flavour profile of GCMSMS analysis of wine from banana cv. Yangambi KM-5

Compounds detected during GCMSMS analysis of Yangambi KM-5 wine

1. Ethanol
2. Methyltartronic acid
3. Ethyl hydrogen succinate
4. Glycerin
5. Phenyl ethyl Alcohol

Data File:	Yangambi KM-5
Injection Volume (µl):	1.00
Run Time (min):	70.02

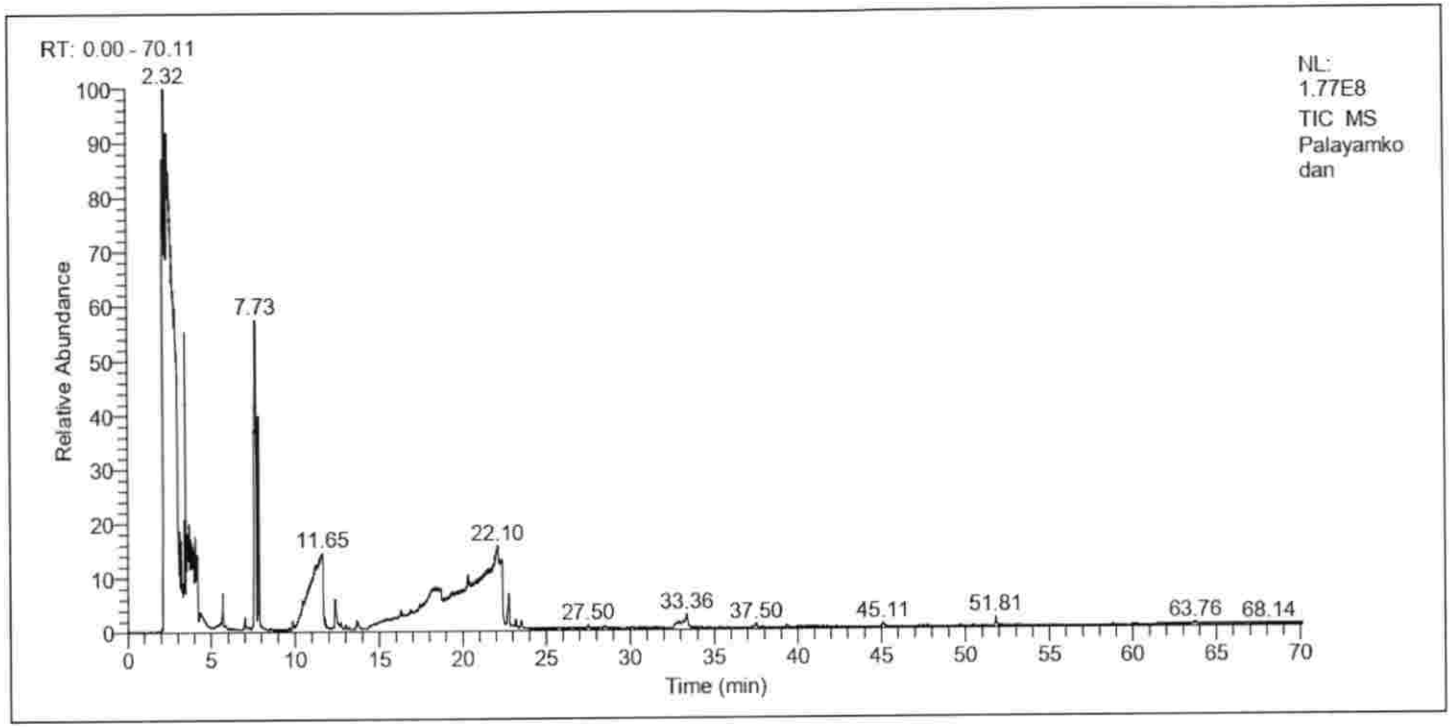

Figure 5: Flavour profile of GCMSMS analysis of wine from banana cv. Palayankodan wine

Compounds detected during GCMSMS analysis of Palayankodan wine

1. Ethanol
2. Phenyl ethyl Alcohol
3. 3(p Hydroxyphenyl) 1propanol
4. Ethyl hydrogen succinate
5. Glycerin

Data File: Palayankodan

Injection Volume (µl):1.00

Run Time (min): 70.02

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Table 19 Effect of ageing on organoleptic quality of banana wine (30DAS)

Treatments	Appearance	Colour	Flavour	Odour	Body	Taste	After taste	Over all acceptability
T1	6.4	7	6.8	6.6	7.2	7.7	7.5	7.5
T2	7.3	6.8	7.4	7.6	7.4	7.5	7.3	7.6
T3	5.8	6.4	5.4	6.2	6.1	6.0	6.1	6.1
T4	7.5	6.5	6.3	5.5	5.3	5.4	5.5	5.6
T5	6	5.6	5.6	6.6	6.4	6.7	6.6	6.2
Kendal's W test	0.708	0.329	0.817	0.677	0.676	0.787	0.678	0.789

DAS-Days after storage

T1-Grand Naine banana wine (Baker's yeast)

T2-Poovan banana wine (Baker's yeast)

T3-Karpooravalli banana wine (Baker's yeast)

T4-Yangambi (KM-5) banana wine (Baker's yeast

T5 –Palayankodan (Baker's yeast)

Table 20 Effect of ageing on organoleptic quality of banana wine (60DAS)

Treatments	Appearance	Colour	Flavour	Odour	Body	Taste	After taste	Over all acceptability
T1	7.5	7.7	7.5	7.4	7.6	7.3	7.6	7.4
T2	7.3	7.3	7.6	7.5	7.7	7.5	7.3	7.6
T3	5.7	5.8	5.9	6.1	5.9	5.9	6.3	5.9
T4	5.3	5.5	5.6	5.6	5.3	5.8	5.8	5.9
T5	6.6	6.5	6.5	6.5	6.8	6.5	6.4	6.5
Kendal's W test	0.816	0.789	0.827	0.703	0.865	0.67	0.744	0.681

DAS-Days after storage

T1-Grand Naine banana wine (Baker's yeast)

T2-Poovan banana wine (Baker's yeast)

T3-Karpooravalli banana wine (Baker's yeast)

T4-Yangambi (KM-5) banana wine (Baker's yeast

T5 –Palayankodan (Baker's yeast)

4.2.1.2.10 Total Yeast population (cfu/ml)

Yeast population decreased during the ageing period (Table 21). The wine from Palayankodan recorded the highest yeast population (8.25×10^3 cfu/ml) and the lowest population was noticed in wine from Grand Naine and Yangambi (7.00×10^3 cfu/ml) after 1 month of ageing, After the completion of ageing, wine prepared from Grand Naine had the highest yeast population (4.00×10^3 cfu/ml) and the lowest was noticed in wine from Palayankodan (3.25×10^3 cfu/ml).

4.2.1.2.11 Total Bacterial population (cfu/ml)

After the 30 days of ageing, bacterial load of banana wine ranged from 0.75 to 1.50×10^5 cfu/ml. The highest bacterial load was found in wine from Yangambi (1.50×10^5 cfu/ml) and the lowest (0.75×10^5 cfu/ml) was recorded in wine from Grand Naine. After the completion of ageing, banana wine from all the varieties showed negligible quantity of bacterial load, which was below the maximum acceptable limits (Table 21).

4.2.1.2.12 Total Fungal population (cfu/ml)

The fungal population decreased throughout the ageing period (Table 21), After 30 days of ageing, the wine from Palayankodan recorded the highest fungal population (0.75×10^3 cfu/ml) and the lowest was noticed in the wine from Poovan (0.25×10^3 cfu/ml). After the completion of ageing, fungal population was detected only in wine from Karpooravalli (0.25×10^3 cfu/ml) whereas, it was not detected in wine from other varieties. The fungal population of banana wine after ageing was below the maximum acceptable limits.

4.2.1.2.13 *Lactobacillus* population (cfu/ml)

The *Lactobacillus* population of banana wine was enumerated at monthly intervals (Table 22). After 30th and 60th days of ageing, wine from Karpooravalli had highest *Lactobacillus* population (0.50×10^4 cfu/ml) and the lowest (0.25×10^4 cfu/ml) was found in wine from (Grand Naine, Poovan Yangambi and Palayankodan). After the completion of ageing, *Lactobacillus* population was not detected in any of the wine samples.

Table 21 Effect of ageing on yeast, bacterial and fungal population of banana wine

Treatments	Total Yeast (10^3 cfu ml^{-1})			Total Bacteria (10^5 cfu ml^{-1})			Total Fungi (10^3 cfu ml^{-1})		
	Initial count	30 DAS	60 DAS	Initial count	30 DAS	60 DAS	Initial count	30 DAS	60 DAS
T1	11.00	7.00	3.50	a	0.75	0.00	a	0.50	0.00
T2	12.00	7.25	4.00	a	1.25	0.25	a	0.25	0.00
T3	11.60	7.50	3.50	a	1.00	0.25	a	0.50	0.25
T4	11.00	7.00	3.50	a	1.50	0.00	a	0.25	0.00
T5	12.00	8.25	3.25	a	1.00	0.00	a	0.75	0.00
CD		NS	NS	-	NS	NS	-	NS	NS

DAS: Days after storage **a**-absent

T1- Grand Naine banana wine (1:2 with pulp and water)

T2-Poovan banana wine (1:2 with pulp and water)

T3-Karpooravalli banana wine (1:1 with pulp and water)

T4-Yangambi (KM-5) banana wine (1:2 with pulp and water)

T5 –Palayankodan (control)

Table 22 Effect of ageing on *Lactobacillus* population of banana wine

Treatments	**Lactobacillus (10^4 cfu ml^{-1})**		
	Initial	**30 DAS**	**60 DAS**
T1	a	0.25	a
T2	a	0.25	a
T3	a	0.50	a
T4	a	0.25	a
T5	a	0.25	a
CD	-	NS	NS

DAS: Days after storage **a**-absent

T1- Grand Naine banana wine (1:2 with pulp and water)

T2-Poovan banana wine (1:2 with pulp and water)

T3-Karpooravalli banana wine (1:1 with pulp and water)

T4-Yangambi (KM-5) banana wine (1:2 with pulp and water)

T5 –Palayankodan (control)

4.3 QUALITY EVALUATION OF WINE DURING STORAGE

After two months of ageing wines was transferred to bottles (amber coloured and plain) and stored under ambient conditions for 3 months. Observations were recorded at monthly intervals to observe the changes in quality during storage.

4.3.1 Biochemical parameters

4.3.1.1 pH

pH of banana wine was evaluated at monthly interval during 3 months of storage (Table 23). pH of all treatments showed an increase trend. After 1 month of storage, treatment T6 (Wine from Karpooravalli stored in amber coloured bottles) recorded the highest pH (3.88) and the lowest (3.72) was observed in T7 (wine from Yangambi (KM-5) stored in plain bottles) whereas, after 2 months of storage, treatment T6 (wine from Karpooravalli stored in amber coloured bottles) recorded the highest pH (3.90) and the lowest (3.74) was noticed in treatment T7 (wine from Yangambi (KM-5) stored in plain bottles). After 90 days of storage, treatment T6 (wine from Karpooravalli stored in amber coloured bottles) recorded highest pH (3.91) and the lowest (3.75) was observed in T7 (wine from Yangambi (KM-5) stored in plain bottles).

4.3.1.2 Total soluble solids (^{0} Brix)

Total soluble solids of banana wine decreased throughout the storage period of 3 months (Table 23). After 1 month of storage, treatment T6 (wine from Karpooravalli stored in amber coloured bottles) recorded highest TSS (4.07 ^{0} Brix) and the lowest (3.81 ^{0} Brix) was noticed in T3 (wine from Poovan stored in plain bottles). After 60 days of storage, treatment T6 (wine from Karpooravalli stored in amber coloured bottles) recorded highest TSS (3.91 ^{0} Brix) and the lowest (3.60 ^{0} Brix) was recorded in treatment T3 (wine from Poovan stored in plain bottles). After 3 months of storage, treatment T6 (wine from Karpooravalli stored in amber coloured bottles) recorded highest TSS (3.81^0 Brix) and the treatment T3 (wine from Poovan stored in plain bottles) recorded the lowest total soluble solids (3.60 ^{0} Brix).

(Plain bottles)
T1- wine from Grand Naine
T3- wine from Poovan
T5- wine from Karpooravalli
T7- wine from Yangambi (KM-5)
T9- wine from Palayankodan

(Amber bottles)
T2- wine from Grand Naine
T4- wine from Poovan
T6- wine from Karpooravalli
T8- wine from Yangambi (KM-5)
T10- wine from Palayankodan
T5- wine from Karpooravalli

Plate 5: Wine kept for storage

Table 23 Effect of storage conditions on pH, Total soluble solids (TSS) and Titratable acidity of banana wine

Treatments	pH				Total soluble solids (°Brix)				Titratable acidity (%)			
	Initial	1MAS	2MAS	3MAS	Initial	1MAS	2MAS	3MAS	Initial	1MAS	2MAS	3MAS
T1	3.73	3.74	3.76	3.77	3.81	3.71	3.64	3.64	1.00	0.97	0.96	0.87
T2		3.75	3.77	3.78		3.81	3.71	3.71		0.98	0.97	0.91
T3	3.80	3.82	3.84	3.85	3.65	3.64	3.60	3.60	0.76	0.70	0.66	0.61
T4		3.83	3.85	3.86		3.71	3.64	3.64		0.72	0.68	0.63
T5	3.85	3.87	3.89	3.90	4.5	3.81	3.74	3.74	0.80	0.86	0.82	0.80
T6		3.88	3.90	3.91		4.07	3.91	3.91		0.88	0.85	0.79
T7	3.69	3.72	3.74	3.75	3.81	3.74	3.64	3.64	0.70	0.76	0.703	0.67
T8		3.74	3.76	3.77		3.81	3.78	3.78		0.79	0.71	0.65
T9	3.82	3.85	3.87	3.88	3.84	3.81	3.78	3.78	0.82	0.81	0.76	0.77
T10		3.86	3.88	3.89		3.84	3.82	3.82		0.81	0.78	0.72
CD	0.036	0.018	0.018	0.018	0.014	0.029	0.020	0.020	0.093	0.015	0.014	0.015

MAS-Months after storage

T1- (Grand Naine) wine stored in plain bottles

T2- (Grand Naine) wine stored in amber coloured bottles

T3-(Poovan) wine stored in plain bottles

T4-(Poovan) wine stored in amber coloured bottles

T5-(Karpooravalli) wine stored in plain bottles

T6-(Karpooravalli) wine stored in amber coloured bottles

T7-(Yangambi KM-5) wine stored in plain bottles

T8-(Yangambi KM-5) wine stored in amber coloured bottles

T9-(Palayankodan) wine stored in plain bottles (control)

T10-(Palayankodan) wine stored in amber coloured bottles (control)

4.3.1.3 Titratable acidity (%)

Titratable acidity of banana wine showed a decreasing trend during storage (Table 23). Treatment T2 (wine from Grand Naine stored in amber coloured bottles) recorded highest titratable acidity (0.98%) and the lowest was in T3 (wine from Poovan stored in plain bottles) (0.70%). Similar trend followed during 2nd and 3rd months of stoarge. Treatment T2 (wine from Grand Naine stored in amber coloured bottles) recorded highest titratable acidity (0.97%) and the lowest (0.66 %) was noticed in T3 (wine from Poovan stored in plain bottles), after 2 months of storage. After 3 months of storage, treatment T2 (wine from Grand Naine stored in amber coloured bottles) recorded the highest (0.91 %) titratable acidity and the lowest was observed in T8 (wine from Yangambi (KM-5) stored in amber coloured bottles) (0.54 %).

4.3.1.4 Reducing sugars (%)

Reducing sugars were not detected in banana wine kept for storage studies (Table 24).

4.3.1.5 Non reducing sugars (%)

Non reducing sugars were not detected in banana wine kept for storage studies (Table 24).

4.3.1.6 Total sugars (%)

Total sugars were not detected in banana wine kept for storage studies (Table 24).

4.3.1.7 Ascorbic acid (mg $100g^{-1}$)

Ascorbic acid of banana wine was evaluated during monthly intervals of storage (Table 25), which showed a decreased trend. After 1 month of storage, treatment T4 (wine from Poovan stored in amber coloured bottles) recorded highest ascorbic acid (1.76 mg $100g^{-1}$) and the lowest (1.48 mg100g-^{1}) was obtained in T1 (wine from Grand Naine stored in plain bottles). After 2 months of storage, treatment T4 (wine from Poovan stored in amber coloured bottles) recorded highest ascorbic acid (1.60 mg$100g^{-1}$) and the lowest (1.26 mg$100g^{-1}$) was noticed in T1 (wine from Grand Naine stored in plain bottles). At the end of storage, treatment T10 (wine from Palayankodan stored in amber coloured bottles) recorded highest ascorbic acid (1.45 mg$100g^{-1}$) and the lowest (1.08 mg $100g^{-1}$) was obtained in T1 (wine from Grand Naine stored in plain bottles).

Table 24 Effect of storage conditions on reducing, non-reducing and total sugar content of banana wine

Treatments	Reducing sugars (%)				Non-reducing sugars (%)				Total sugars (%)			
	Initial	1MAS	2MAS	3MAS	Initial	1MAS	2MAS	3MAS	Initial	1MAS	2MAS	3MAS
T1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
T2		ND	ND	ND		ND	ND	ND		ND	ND	ND
T3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
T4		ND	ND	ND		ND	ND	ND		ND	ND	ND
T5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
T6		ND	ND	ND		ND	ND	ND		ND	ND	ND
T7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
T8		ND	ND	ND		ND	ND	ND		ND	ND	ND
T9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
T10		ND	ND	ND		ND	ND	ND		ND	ND	ND
CD	-	-	-	-	-	-	-	-	-	-	-	-

MAS-Months after storage
ND- Not detected

T1- (Grand Naine) wine stored in plain bottles
T2- (Grand Naine) wine stored in amber coloured bottles
T3-(Poovan) wine stored in plain bottles
T4--(Poovan) wine stored in amber coloured bottles
T5-(Karpooravalli) wine stored in plain bottles
T6-(Karpooravalli) wine stored in amber coloured bottles
T7-(Yangambi KM-5) wine stored in plain bottles
T8-(Yangambi KM-5) wine stored in amber coloured bottles
T9-(Palayankodan) wine stored in plain bottles (control)
T10-(Palayankodan) wine stored in amber coloured bottles (control)

Table 25 Effect of storage conditions on ascorbic acid, phenol and alcohol content of banana wine

Treatments	Ascorbic acid(mg $100g^{-1}$)				Phenols (mg $100g^{-1}$)				Alcohol (%)			
	Initial	1MAS	2MAS	3MAS	Initial	1MAS	2MAS	3MAS	Initial	1MAS	2MAS	3MAS
T1	1.608	1.42	1.26	1.08	40.5	34.50	31.00	27.16	8.408	8.50	8.91	8.91
T2		1.44	1.28	1.12		36.33	33.00	26.00		8.53	9.17	9.17
T3	1.91	1.60	1.44	1.40	44.25	38.50	34.00	30.50	9.47	9.53	9.60	9.60
T4		1.76	1.60	1.44		40.50	36.67	28.00		9.56	9.28	9.28
T5	1.98	1.50	1.44	1.26	41.37	37.00	31.30	26.50	9.36	9.41	9.50	9.50
T6		1.52	1.45	1.28		38.83	30.33	26.33		9.41	9.62	9.62
T7	1.90	1.48	1.39	1.34	56.25	44.33	37.00	33.50	9.57	9.64	9.72	9.72
T8		1.50	1.44	1.39		46.50	38.00	33.00		9.67	9.80	9.80
T9	1.60	1.58	1.52	1.42	42.25	35.00	31.00	25.50	9.64	9.73	9.82	9.82
T10		1.60	1.55	1.45		38.16	32.00	27.00		9.75	9.85	9.85
CD	0.015	0.017	0.017	0.017	1.316	1.301	1.616	1.282	0.087	0.013	0.104	0.104

MAS-Months after storage

T1- (Grand Naine) wine stored in plain bottles

T2- (Grand Naine) wine stored in amber coloured bottles

T3-(Poovan) wine stored in plain bottles

T4--(Poovan) wine stored in amber coloured bottles

T5-(Karpooravalli) wine stored in plain bottles

T6-(Karpooravalli) wine stored in amber coloured bottles

T7-(Yangambi KM-5) wine stored in plain bottles

T8-(Yangambi KM-5) wine stored in amber coloured bottles

T9-(Palayankodan) wine stored in plain bottles (control)

T10-(Palayankodan) wine stored in amber coloured bottles (control)

4.3.1.8 Total phenols (mg $100g^{-1}$)

Phenol content of banana wine showed a decreasing trend during storage (Table 25). After 1 month of storage, treatment T8 (wine from Yangambi stored in amber coloured bottles) recorded highest phenols (46.50 mg $100g^{-1}$) and the lowest (34.50 mg$100g^{-1}$) was obtained in T1 (wine from Grand Naine stored in plain bottles).After 2 months of storage, treatment T8 (wine from Yangambi stored in amber coloured bottles) recorded highest phenols (38.00 mg$100g^{-1}$) and the lowest (30.33 mg $100g^{-1}$) was noticed in T6 (wine from Karpooravalli stored in amber coloured bottles). At the end of storage, treatment T7 (wine from Yangambi stored in plain bottles) recorded highest phenols (33.5 mg$100g^{-1}$) and the lowest (25.5 mg $100g^{-1}$) was recorded in T9 (wine from Palayankodan stored in plain bottles).

4.3.1.9 Alcohol (%)

Alcohol content of banana wine revealed an increasing trend during storage (Table 25). Treatment T10 (wine from Palayankodan stored in amber coloured bottles) recorded highest alcohol content (9.75%) and the lowest (8.50%) was in T1 (wine from Grand Naine stored in plain bottles). Treatment T10 (wine from Palayankodan stored in amber coloured bottles) had highest alcohol content (9.85%) and the lowest (8.72 %) was noticed in T2 (wine from Grand Naine stored in amber coloured bottles), after 2 months of storage. After 3 months of storage, treatment T10 (wine from Palayankodan stored in amber coloured bottles) recorded the highest alcohol content (9.85%) and the lowest (8.91 %) was in T1 (wine from Grand Naine stored in plain bottles).

4.3.1.10 Sensory evaluation

Organoleptic evaluation of wine was done during monthly intervals of storage (Table 26, 27 and 28). The wine was stored in plain and amber coloured bottles. After 30 days of storage, treatment T4 (wine from Poovan stored in amber coloured bottles) had highest overall acceptability score (7.6) and the lowest (5.6) was in T7 (wine from Yangambi stored in plain bottles). Treatment T4 (wine from Poovan stored in amber coloured bottles) had highest overall acceptability score (7.6) and the lowest (5.4) was in T7 (wine from Yangambi stored in plain bottles), after 2 months of storage. After 3 months of storage, treatment T4 (wine from Poovan stored in amber coloured bottles) had highest overall acceptability score (7.4) and the lowest (5.5) was in T7 (wine from Yangambi stored in plain bottles). The wine stored in amber coloured bottles had higher sensory scores when compared that in plain bottles.

4.3.1.11 Yeast population (cfu/ml)

The yeast population was 0.3×10^3 in the banana wine from various varieties stored after 1 month of storage (Table 31). Thereafter, the yeast population declined and yeast could not be detected after 2^{nd} and 3^{rd} months of storage.

4.3.1.12 Bacterial population (cfu/ml)

Bacteria could not be detected in any of the wine samples during the entire period of storage (Table 31).

4.3.1.13 Fungal population (cfu/ml)

Fungal population could not be detected in any of the wine samples during the entire period of storage (Table 31).

4.3.1.14 *Lactobacillus* population (cfu/ml)

Lactobacillus population could not be detected in any of the wine samples during the entire period of storage (Table 32).

Table 26 Effect of storage on organoleptic quality of banana wine (1MAS)

Treatments	Appearance	Colour	Flavour	Odour	Body	Taste	After taste	Over all acceptability
T1	6.5	6.3	6.5	6.4	6.3	6.7	6.5	6.7
T2	6.8	7.2	6.9	7.0	6.4	6.7	7.4	7.3
T3	6.5	6.6	6.6	6.5	6.7	6.4	6.3	6.5
T4	7.4	7.1	7.4	7.4	7.6	7.3	7.6	7.6
T5	5.6	5.8	5.9	6.2	5.7	6.0	6.2	5.6
T6	6.3	6.6	6.5	6.5	6.4	6.4	6.5	6.6
T7	5.4	5.7	5.5	5.4	5.5	5.4	5.5	5.6
T8	5.7	6.1	5.9	6	6.4	6.0	5.8	6.1
T9	6.4	6.9	6.5	6.5	6.7	6.2	6.5	6.4
T10	6.7	7.1	7.0	6.8	6.8	6.4	6.8	6.8
Kendal's W test	0.467	0.504	0.417	0.412	0.452	0.406	0.55	.480

T1- (Grand Naine) wine stored in plain bottles

T2- (Grand Naine) wine stored in amber coloured bottles

T3-(Poovan) wine stored in plain bottles

T4--(Poovan) wine stored in amber coloured bottles

T5-(Karpooravalli) wine stored in plain bottles

T6-(Karpooravalli) wine stored in amber coloured bottles

T7-(Yangambi KM-5) wine stored in plain bottles

T8-(Yangambi KM-5) wine stored in amber coloured bottles

T9-(Palayankodan) wine stored in plain bottles (control)

T10-(Palayankodan) wine stored in amber coloured bottles (control)

MAS- Months after storage

Table 27 Effect of storage on organoleptic quality of banana wine (2MAS)

Treatments	Appearance	Colour	Flavour	Odour	Body	Taste	After taste	Over all acceptability
T1	6.6	6.2	6.5	6.7	6.6	6.3	6.6	6.7
T2	6.6	7.1	7.4	7.2	6.9	7.4	6.7	6.6
T3	6.4	6.1	6.7	6.5	6.6	6.7	6.4	6.4
T4	7.3	7.2	7.5	7.7	7.7	7.6	7.4	7.6
T5	5.9	5.9	6.2	6.4	5.8	6.4	5.5	6.0
T6	6.4	6.5	6.3	6.4	6.6	6.6	6.5	6.6
T7	5.3	5.6	5.4	5.7	5.7	5.0	5.6	5.4
T8	6.0	6.3	6.2	5.8	6.1	6.0	6.0	6.1
T9	6.5	6.5	6.4	6.5	6.4	6.3	6.5	6.4
T10	6.7	6.7	6.6	7.0	6.8	7.2	6.8	6.6
Kendal's W test	0.36	0.412	0.461	0.443	0.396	0.658	0.424	0.435

T1- (Grand Naine) wine stored in plain bottles

T2- (Grand Naine) wine stored in amber coloured bottles

T3-(Poovan) wine stored in plain bottles

T4--(Poovan) wine stored in amber coloured bottles

T5-(Karpooravalli) wine stored in plain bottles

T6-(Karpooravalli) wine stored in amber coloured bottles

T7-(Yangambi KM-5) wine stored in plain bottles

T8-(Yangambi KM-5) wine stored in amber coloured bottles

T9-(Palayankodan) wine stored in plain bottles (control)

T10-(Palayankodan) wine stored in amber coloured bottles (control)

MAS- Months after storage

Table 28 Effect of storage on organoleptic quality of banana wine (3MAS)

Treatments	Appearance	Colour	Flavour	Odour	Body	Taste	After taste	Over all acceptability
T1	6.5	6.5	6.6	6.6	6.6	6.6	6.3	6.5
T2	6.9	7.3	7.0	6.9	7.3	6.5	7	7.2
T3	6.6	6.5	6.4	6.5	6.3	6.6	6.3	6.7
T4	7.5	7.4	7.6	7.8	7.5	7.1	7.3	7.4
T5	6.0	6.2	5.7	6.1	5.9	5.8	6	6.0
T6	6.5	6.3	6.4	6.3	6.4	6.7	6.4	6.2
T7	5.5	5.5	5.4	5.7	5.3	5.4	5.9	5.5
T8	5.8	6.0	6.2	6.2	6.1	5.8	6.4	6.0
T9	6.2	6.4	6.6	6.2	6.7	6.7	6.4	6.7
T10	6.8	6.8	6.7	6.9	6.6	6.5	6.6	7.0
Kendal's W test	0.483	0.438	0.531	0.444	0.538	0.429	0.282	0.467

T1- (Grand Naine) wine stored in plain bottles

T2- (Grand Naine) wine stored in amber coloured bottles

T3-(Poovan) wine stored in plain bottles

T4--(Poovan) wine stored in amber coloured bottles

T5-(Karpooravalli) wine stored in plain bottles

T6-(Karpooravalli) wine stored in amber coloured bottles

T7-(Yangambi KM-5) wine stored in plain bottles

T8-(Yangambi KM-5) wine stored in amber coloured bottles

T9-(Palayankodan) wine stored in plain bottles (control)

T10-(Palayankodan) wine stored in amber coloured bottles (control)

MAS- Months after storage

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Table 29 Effect of storage conditions on yeast, fungi and bacteria population of banana wine

Treatments	Yeast(10^3 cfu ml^{-1})				Fungi (10^3 cfu ml^{-1})				Bacteria ((10^5 cfu ml^{-1})			
	Initial	MAS	2MAS	3MAS	Initial	1MAS	2MAS	3MAS	Initial	1MAS	2MAS	3MAS
T1	3.5	0.3	a	a	ND	a	a	a	ND	a	a	a
T2		0.3	a	a		a	a	a		a	a	a
T3	4.0	0.3	a	a	0.5	a	a	a	0.25	a	a	a
T4		0.3	a	a		a	a	a		a	a	a
T5	3.5	0.3	a	a	ND	a	a	a	0.25	a	a	a
T6		0.3	a	a		a	a	a		a	a	a
T7	3.5	0.3	a	a	ND	a	a	a	ND	a	a	a
T8		0.3	a	a		a	a	a		a	a	a
T9	3.2	0.3	a	a	ND	a	a	a	ND	a	a	a
T10		0.3	a	a		a	a	a		a	a	a
CD	-	-	-	-	-	-	-	-	-	-	-	-

MAS-Months after storage
a- absent

T1- (Grand Naine) wine stored in plain bottles

T2- (Grand Naine) wine stored in amber coloured bottles

T3-(Poovan) wine stored in plain bottles

T4--(Poovan) wine stored in amber coloured bottles

T5-(Karpooravalli) wine stored in plain bottles

T6-(Karpooravalli) wine stored in amber coloured bottles

T7-(Yangambi KM-5) wine stored in plain bottles

T8-(Yangambi KM-5) wine stored in amber coloured bottles

T9-(Palayankodan) wine stored in plain bottles (control)

T10-(Palayankodan) wine stored in amber coloured bottles (control)

Table 30 Effect of storage conditions on *Lactobacillus* population of banana wine

Treatments	Lactobacillus (10^4 cfu ml^{-1})			
	Initial	1MAS	2MAS	3MAS
T1	a	a	a	a
T2		a	a	a
T3	a	a	a	a
T4		a	a	a
T5	a	a	a	a
T6		a	a	a
T7	0.25	a	a	a
T8		a	a	a
T9	a	a	a	a
T10		a	a	a
CD	-	-	-	-

MAS- Months after storage
a- absent

T1- (Grand Naine) wine stored in plain bottles

T2- (Grand Naine) wine stored in amber coloured bottles

T3-(Poovan) wine stored in plain bottles

T4--(Poovan) wine stored in amber coloured bottles

T5-(Karpooravalli) wine stored in plain bottles

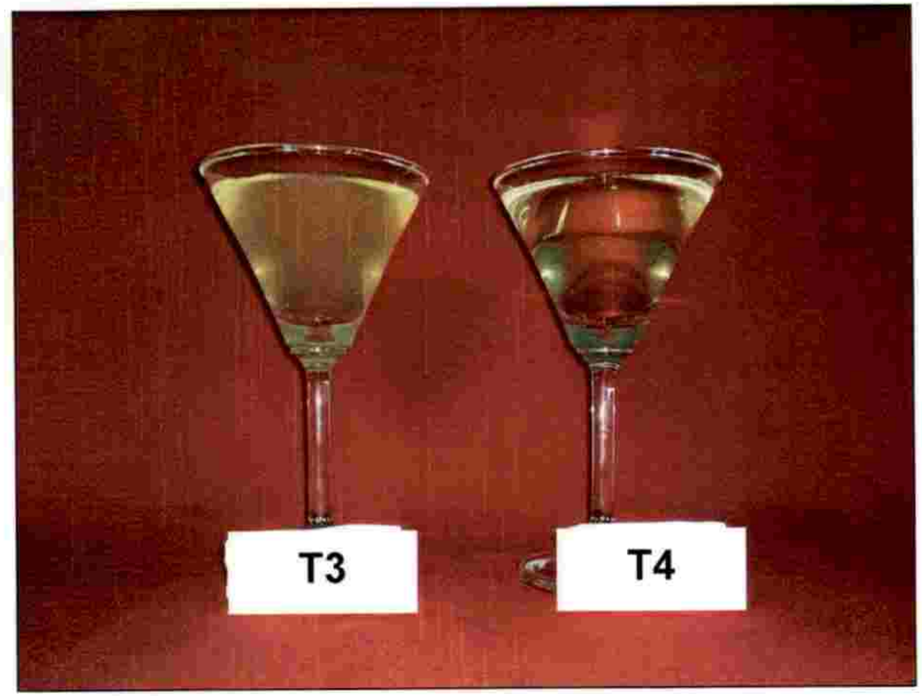
T6-(Karpooravalli) wine stored in amber coloured bottles

T7-(Yangambi KM-5) wine stored in plain bottles

T8-(Yangambi KM-5) wine stored in amber coloured bottles

T9-(Palayankodan) wine stored in plain bottles (control)

T10-(Palayankodan) wine stored in amber coloured bottles (control)



T1- (Grand Naine) wine stored in plain bottles

T2- (Grand Naine) wine stored in amber coloured bottles

T3- (Poovan) wine stored in plain bottles

T4- (Poovan) wine stored in amber coloured bottles

Plate 6a: Wine after storage

T5- (Karpooravalli) wine stored in plain bottles

T6- (Karpooravalli) wine stored in amber coloured

T7- (Yangambi KM-5) wine stored in plain bottles

T8- (Yangambi KM-5) wine stored in amber coloured

Plate 6b: Wine after storage

T9- (Palayankodan) wine stored in plain bottles

T10- (Palayankodan) wine stored in amber coloured bottles

Plate 6c: Wine after storage

Discussion

5. DISCUSSION

The discussion pertaining to the study is presented under the following heads.

5.1 Evaluation of banana varieties for quality wine production

5.2 Quality evaluation of wine during storage/ageing

5.1 EVALUATION OF BANANA VARIETIES FOR QUALITY WINE PRODUCTION

The different banana varieties (Grand Naine, Karpooravalli, Poovan, Yangambi (KM-5) and Palayankodan) were collected from various localities of Thrissur.

5.1.1 Biochemical characteristics of banana varieties

Banana varieties selected for wine making (Grand Naine, Poovan, Karpooravalli, Yangambi (KM-5) and Palayankodan) were evaluated for the biochemical characteristics (Table1). Among the varieties highest total soluble solids (22.0 ^{0}Brix) was recorded in Yangambi (KM-5) and lowest in Palayankodan (18 ^{0} Brix). The pH was highest in Palayankodan (4.72) and lowest in Grand Naine (4.12). Ascorbic acid content was highest in Poovan (2.81 mg 100g $^{-1}$) and lowest in Palayankodan (2.24 mg 100g $^{-1}$). The variety Karpooravalli had the highest titratable acidity (0.51%) and Grand Naine recorded the lowest (0.39%). Specific gravity was highest (1.062) in varieties like Karpooravalli, Grand Naine and Palayankodan and lowest (1.061) in Yangambi and Poovan. Moisture content was highest in Grand Naine (84.51%) and lowest (71.98%) in Karpooravalli. Grand Naine had the highest ash (8.65%) and protein content (7.62 %) whereas the lowest ash (5.36%) and protein (4.79%) content was recorded in Karpooravalli. The fat content of was highest (1.36%) in Karpooravalli and lowest in Palayankodan (0.61%).

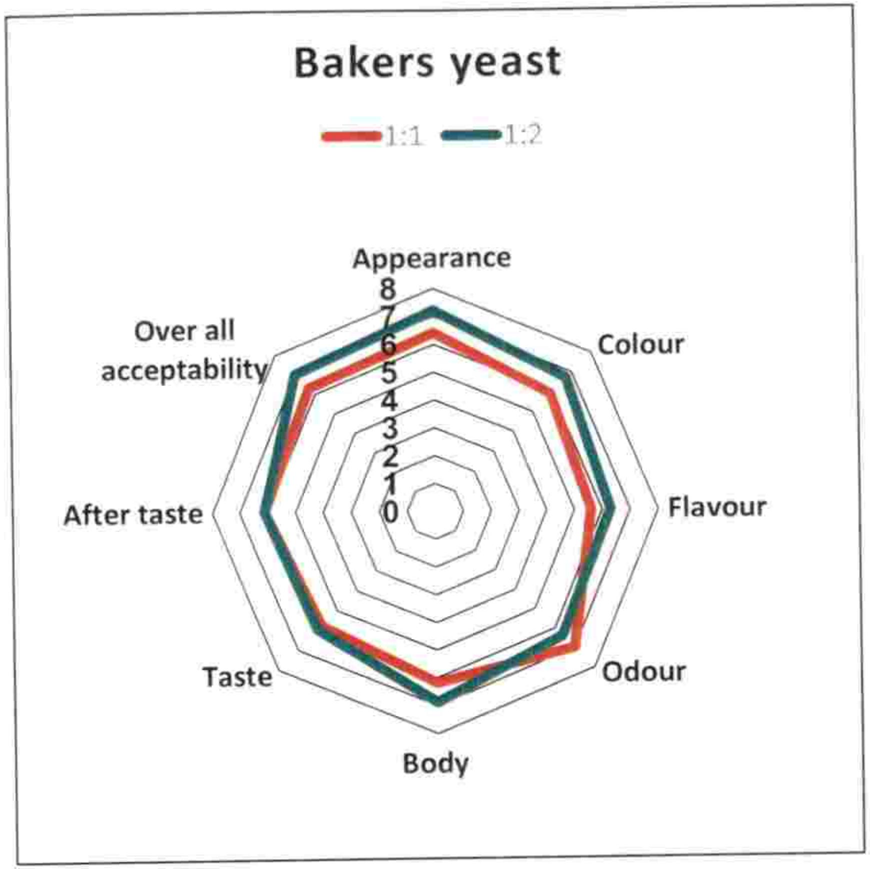
Deshmukh *et al.* (2009) reported that banana variety Grand Naine had an ascorbic acid content of 2.00 mg $100g^{-1}$ and ash content of 5.36%. Narayana *et al.* (2017) reported that banana varieties such as Poovan and Karpooravalli had moisture content of 70 and 62%, respectively. Reni (2005), reported that banana varieties such as Grand Naine, Poovan, Palayankodan and Karpooravalli had TSS of 28.5,29.5,25.5 and 29.5 ^{0}Brix, acidity of 0.32, 0.44, 0.41 and 0.41 %, pH of 4.5, 4.6, 4.3 and 4.2, ascorbic acid content of 2.2, 2.6, 2.8 and 2.07 mg $100g^{-1}$, respectively.

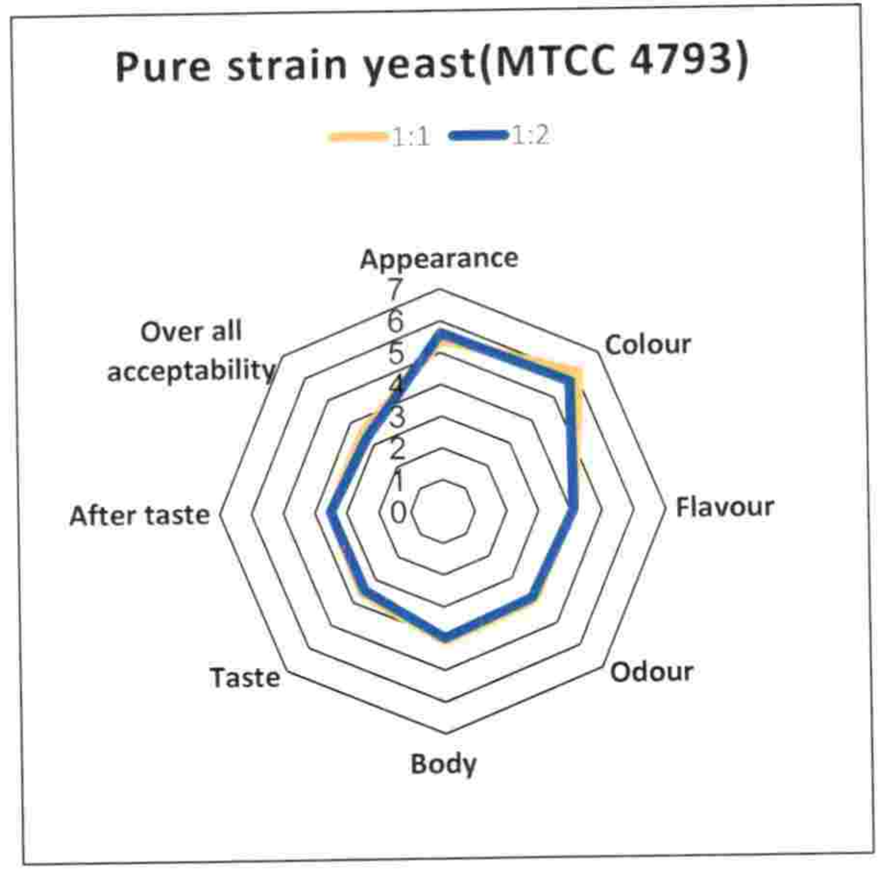
5.1.2 Nutritive and biochemical parameters

5.1.2.1 Sensory evaluation

Banana wine from varieties Grand Naine,Poovan,Yangambi and Palayankodan prepared with pulp :water ratio of 1:2 had better organoleptic acceptability whereas the wine from Karpooravalli with 1:1 ratio of pulp and water was organoleptically superior than the wine from 1:2 ratio of pulp and water. Flavour of fruit wines is a result of the intrinsic combination of their biochemical consituents like alcohol,organic acids,volatile compounds,phenols,total soluble solids etc.Wine from all varieties except Karpooravalli in 1:2 ratio of pulp and water may have resulted in a mild and mellow flavour due to the higher dilution as compared to the wine from Karpooravalli in the same ratio, whereas the presence of 1- deoxy-d-arabitol in wine from Karpooravalli may have contributed to its unique flavour and the resultant better acceptability of wine from this variety in 1:1 ratio. Sensory evaluation of wine prepared using pure wine yeast revealed that this wine was not acceptable as all treatments had a score less than 5.5. The wine prepared using the strain MTCC 4793 might be homofermentative in nature and also production of volatile acidity with sour taste may have resulted in lower scores due to the inferior organoleptic properties.

(Egwim *et al.,* 2013), reported better colour, taste, texture and overall acceptability scores for banana wine as compared to wine from papaya. Kumar *et al*. (2011) reported that custard apple wine with higher dilution was more acceptable than the one with lower dilution. (Moreno *et al.,* 1990) reported that grape wine prepared using pure strain of *Saccharomyces cerevisiae* had higher production of volatile acidity than the native yeasts. (Ciani *et al.,*2010) reported that the combined fermentation of pure culture yeast and indigenous yeast led to production of negative metabolites in wine making. (Alvarenga *et al.,*2011) evaluated different strains (UNICAMP-V1, UFMG-A905, UFMG-A1007 and UFMG-A1240) of *Saccharomyces cerevisiae* along with commercial yeast on banana pulp fermentation and found that commercial yeast and a strain named UNICAMP-V1 showed better results, whereas the other pure strains (UFMG-A905, UFMG-A1007 and UFMG-A1240) had negative results.





Ratio of pulp and water-1:1 and 1:2

Figure 6: Effect of ratio of pulp and water on sensory attributes of wine from Grand Naine

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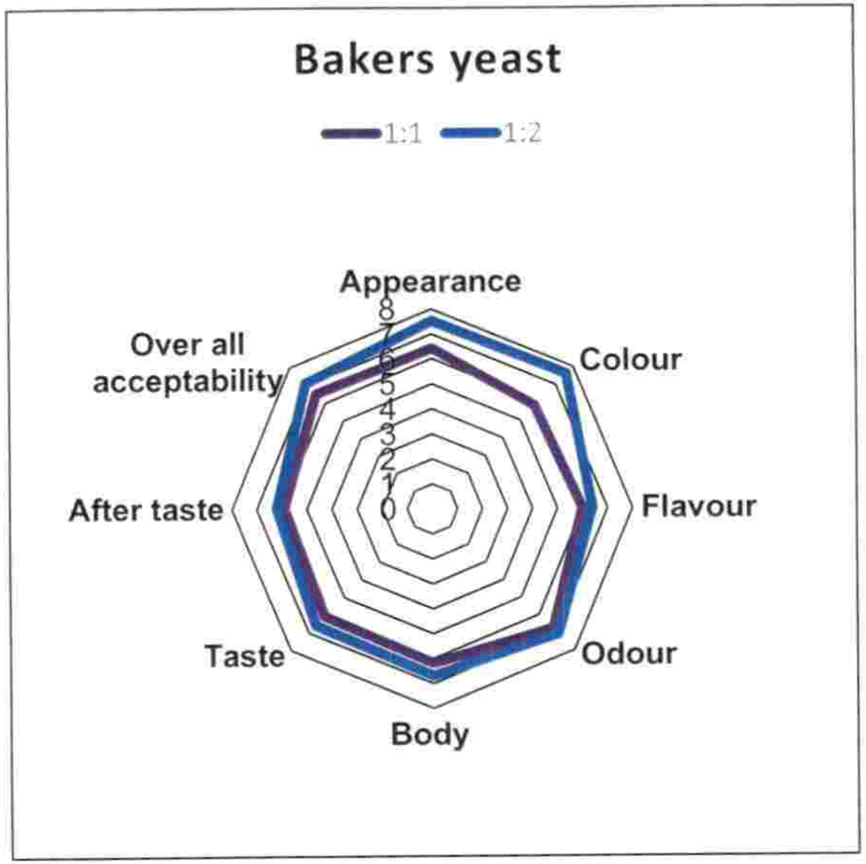
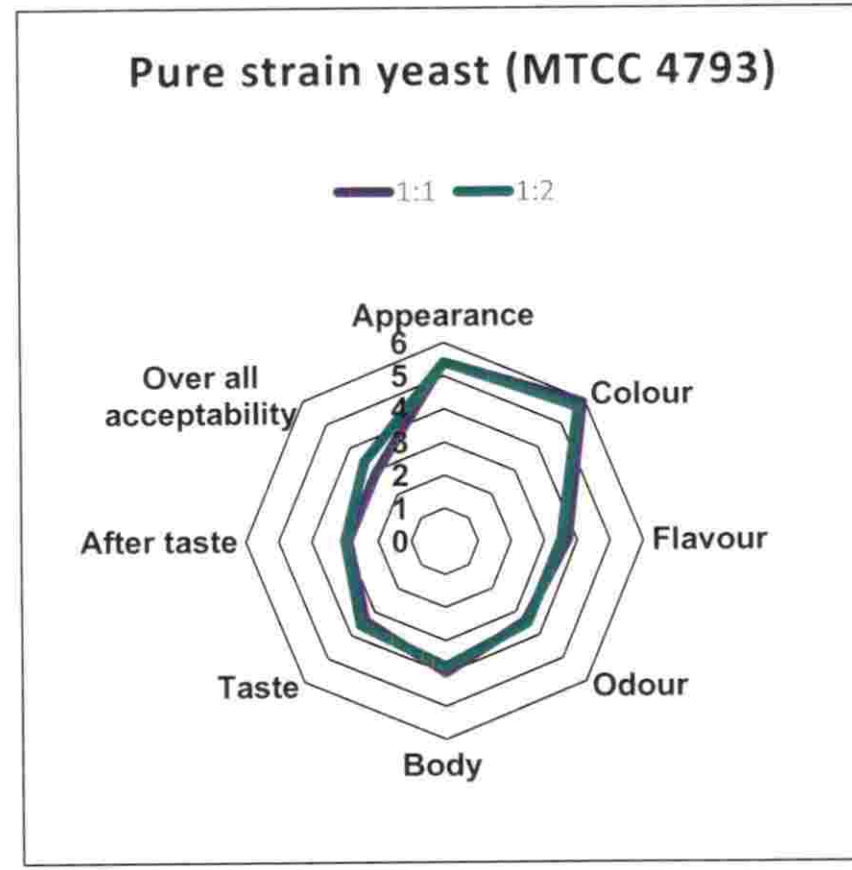
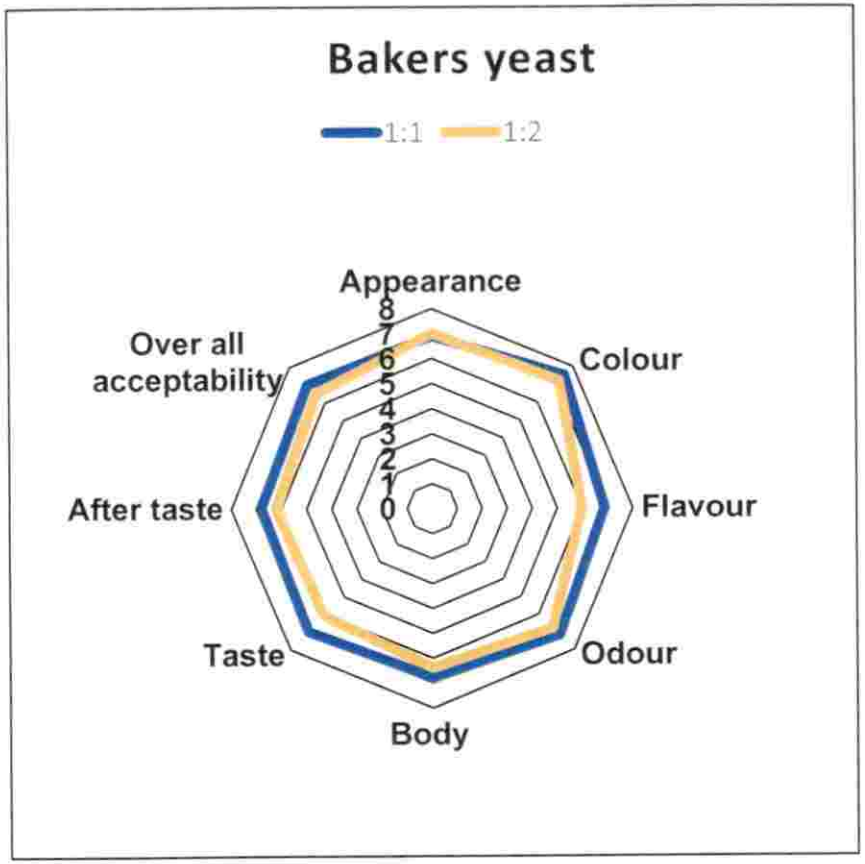
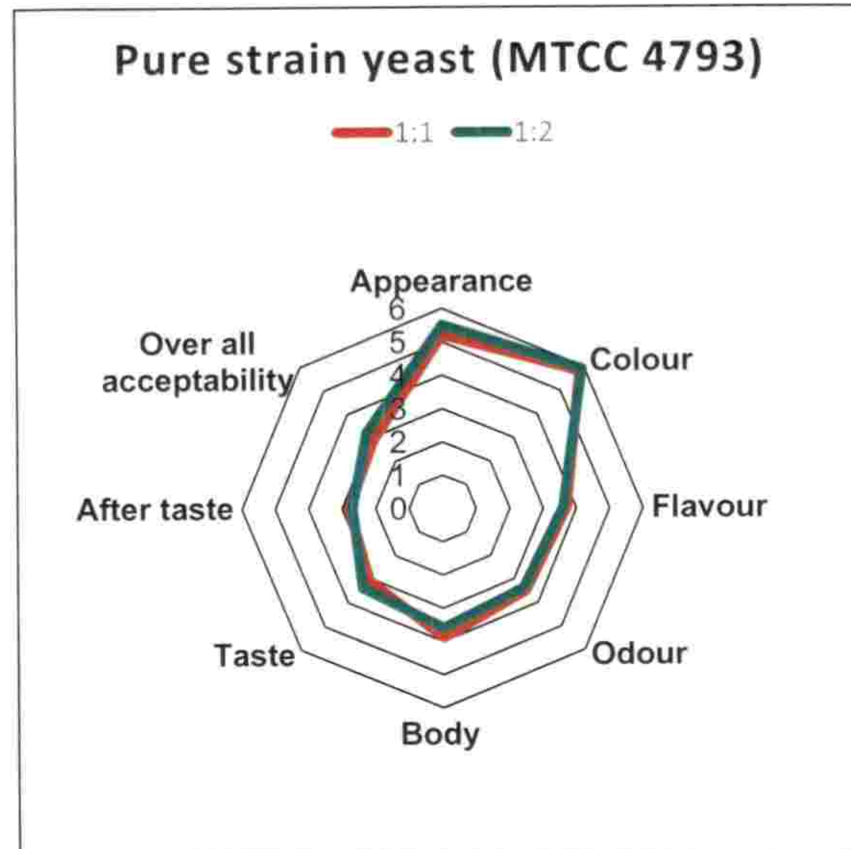




Ratio of pulp and water-1:1 and 1:2

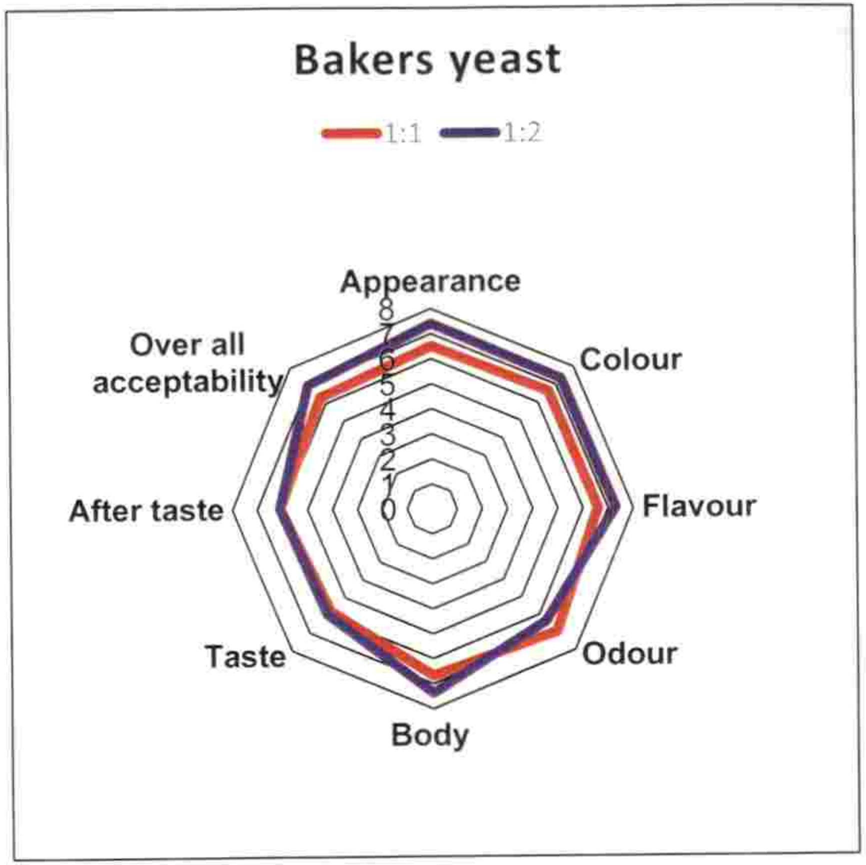
Figure 7: Effect of ratio of pulp and water on sensory attributes of wine from Poovan

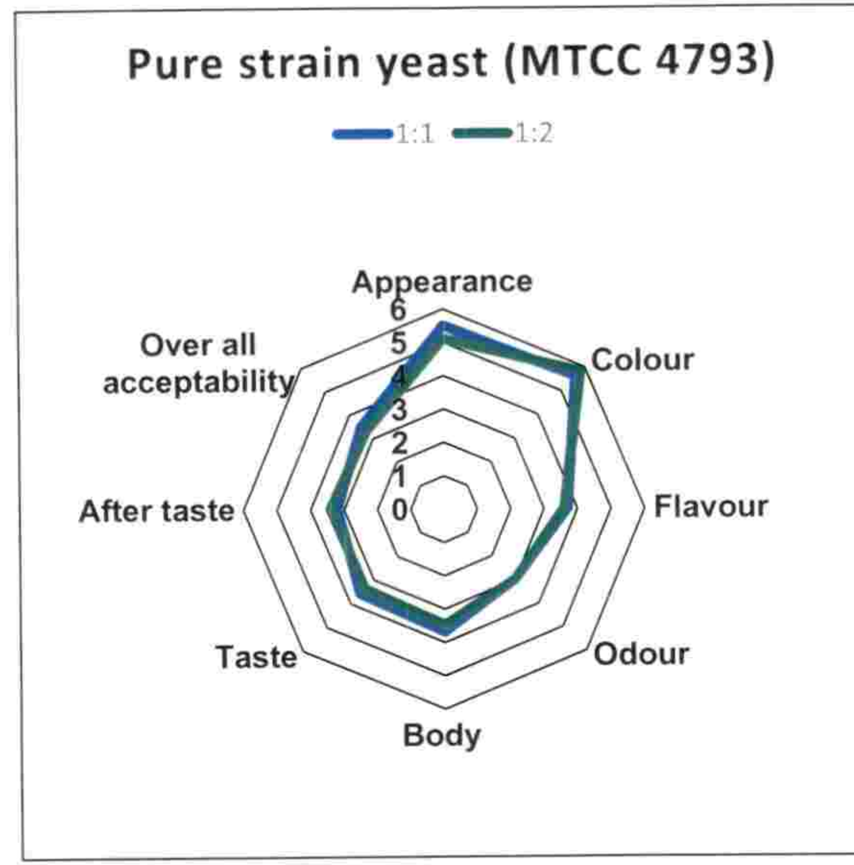




Ratio of pulp and water-1:1 and 1:2

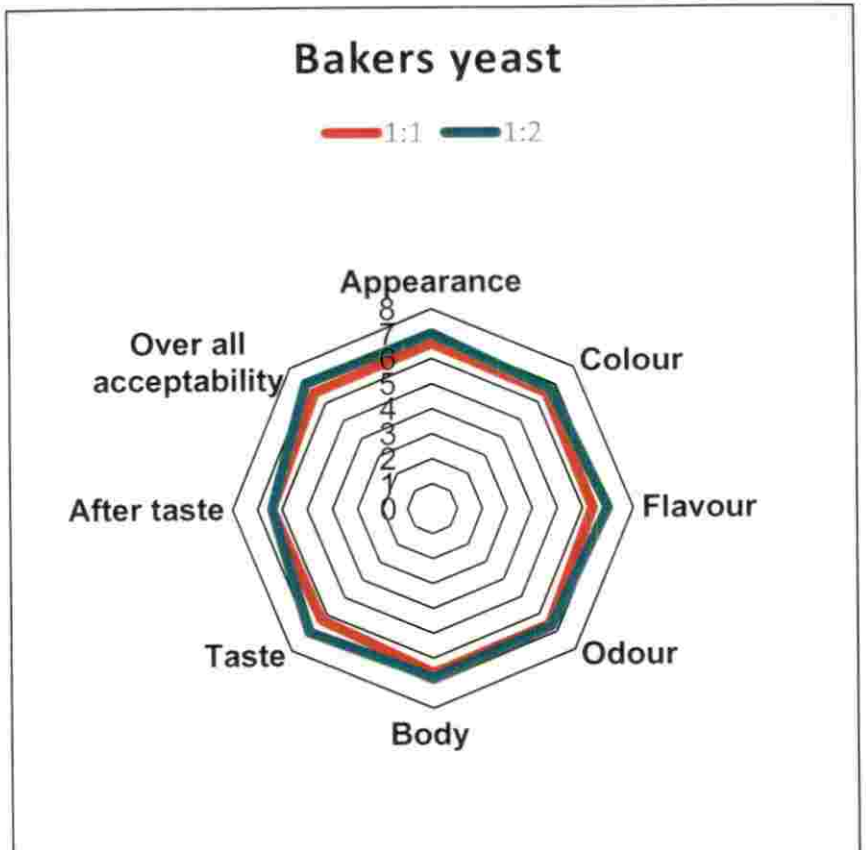
Figure 8: Effect of ratio of pulp and water on sensory attributes of wine from Karpooravalli

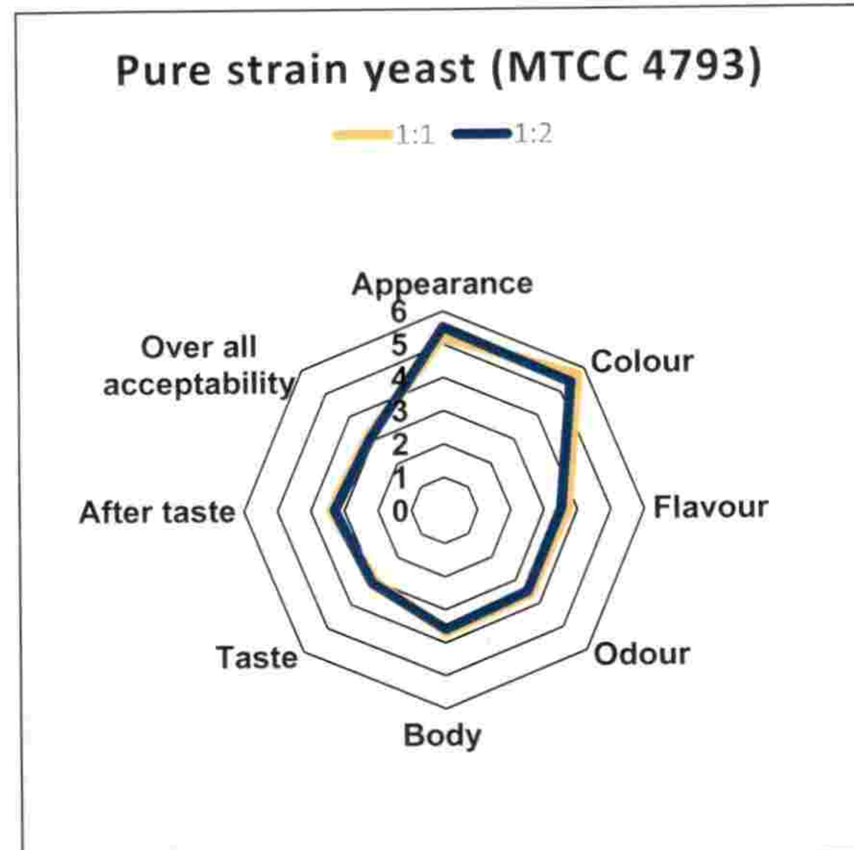




Ratio of pulp and water-1:1 and 1:2

Figure 9: Effect of ratio of pulp and water on sensory attributes of wine from Yangambi KM-5





Ratio of pulp and water-1:1 and 1:2

Figure 10: Effect of ratio of pulp and water on sensory attributes of wine from Palayankodan

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5.1.2.2 pH

The pH of wine from various banana varieties ranged from 3.43 to 4.64. Wine from all varieties of banana prepared with pulp and water ratio of 1:1 had higher pH than the wine prepared with 1:2 ratio of pulp and water. Wine from Yangambi with pulp and water ratio of 1:1 had the highest pH (4.64) and the lowest (3.43) was in the wine from the variety Grand Naine with pulp and water ratio of 1:2

The higher dilution might have reduced the pH of wine. The variation in pH in banana wine is due to breakdown of sugars by the yeast (Nwobodo, 2013). Reduction in volatile acids and microflora usage of acids might be the reason for variation in pH of banana wine (Satave and Pethe, 2016). Kundu *et al*. (1976), reported that banana pulp with water in 1:1 ratio had higher pH than the one diluted in 1:2 ratio. Shankar *et al* (2002), reported that wine from guava with higher dilution had lower pH than the wine prepared from lower dilution.

5.1.2.3 Total soluble solids (TSS)

Wine from all varieties of banana prepared with pulp and water ratio of 1:1 had higher total soluble solids than the wine prepared with 1:2 ratio of pulp and water. Wine from Grand Naine (1:1) had the highest total soluble solids (5.1 ^{0}Brix) and the lowest (4.0 ^{0}Brix) was in the wine from the varieties Yangambi and Poovan with pulp and water ratio of 1:2.

Sugars constitute the major fraction of total soluble solids which is an indication of the sweetness of wine. Higher dilution may have reduced the concentration of total soluble solids resulting in lowering the TSS of wine prepared from pulp: water ratio of 1:2 when compared to 1:1 ratio of pulp and water. Utilization of sugars by breaking down total soluble solids for the production of alcohol by yeast might have lowered the TSS content of wine in all the samples (Pawar, 2009; Satave and Pethe, 2016). Similar findings were reported in jamun wine where lower dilution (1:1) had higher TSS (10.2 ^{0}Brix) than 1:2 (8.8 ^{0}Brix) (Joshi *et al.*, 2011).

5.1.2.4 Titratable acidity (%)

Wine from all varieties of banana prepared with pulp and water ratio of 1:1 had higher titratable acidity than the wine prepared with 1:2 ratio of pulp and water. Wine from Palayankodan with pulp and water ratio of 1:1 had the highest titratable acidity (1.37 %) and the lowest (0.80%) was in the wine from the variety Poovan with pulp and water ratio of 1:2.

The higher dilution of pulp might have led to lowering the concentration of organic acids. The amount of total organic acids determines the titratable acidity of wine (Wardai, 2014). During alcohol fermentation of white wine, acid produced is accumulated in the form of salts (Rajkovic *et al.*, 2007). The deviation in the level of titratable acidity is due to differences in methods of preparation of strawberry wine (Sharma and Joshi, 2009). The higher dilution of pulp led to lowering the quantity of pulp which resulted in lesser acidity in jamun wine prepared from 1:2 ratio of pulp and water as compared to 1:1 ratio (Joshi *et al.*, 2011).

5.1.2.5 Reducing, non reducing and total sugars (%)

Sugars could not be detected in the wine from any of the banana varieties.This might be due to the conversion of sugars into alcohol by yeast during fermentation which resulted in its negligible quantity in the product. Similar findings were reported in guava wine where reducing sugars were reduced from 25 % to 0% during 7 days of fermentation period. (Nikhanj and Kocher, 2011). Wine prepared from jamun had reducing sugars of 0.18% (Shukla *et al.*, 1991).

5.1.2.6 Ascorbic acid (mg $100g^{-1}$)

Wine from all varieties of banana prepared with pulp and water ratio of 1:1 had higher ascorbic acid than the wine prepared with 1:2 ratio of pulp and water. Wine from Poovan with pulp and water ratio of 1:1 had the highest ascorbic acid content (2.28 mg $100g^{-1}$) and the lowest (1.64 mg $100g^{-1}$) was in the wine from the variety Karpooravalli with pulp and water ratio of 1:2.

Ascorbic acid content of wine depends upon the quantity of ascorbic acid present in the must. Higher dilution of pulp (1:2) may have lowered the initial ascorbic acid content of the must which resulted in lower levels of ascorbic acid in the final product. Ascorbic acid showed decreasing trend during fermentation of the must into wine from 2 mg $100g^{-1}$ to 1.52 mg $100g^{-1}$ in tendu (*Diospyros melanoxylon*) fruit wine. (Sahu *et al.*, 2012). Reduction of ascorbic acid content was likely caused by heat or oxidation destruction and it reduced from 9 mg $100g^{-1}$ to 1.4 mg $100g^{-1}$ in banana wine (Akbour *et al.*, 2003).

5.1.2.7 Total phenols (mg $100g^{-}1$)

Banana wine prepared from different varieties with pulp and water ratio of 1:1 had higher total phenols than the wine prepared with 1:2 ratio of pulp and water. Wine from Yangambi with pulp and water ratio of 1:1 had the highest total phenols (85 mg $100g^{-1}$) and the lowest (59.6 mg $100g^{-1}$) was in the wine from the variety Poovan with pulp and water ratio of 1:2.

The level of phenols in wine naturally comes from the pulp. The reduced content of phenols in wine prepared from 1:2 ratio of pulp and water is due to the higher dilution of the pulp. Kumar *et al.* (2011), reported reduction in the levels of phenols in wine prepared from custard apple at higher dilution. Rupasinghe *et al.* (2017), stated that fermentation, bioavailability and biological impacts are directly influenced by the chemistry of fruit phenolics. Similar findings were reported in jamun wine where higher dilution (1:2) had lower phenols (32 mg $100g^{-1}$) than 1:1 (36 mg $100g^{-1}$) dilution (Joshi *et al.*, 2011). Panda *et al.* (2014), reported that the increase in pH led to auto oxidation of polyphenols in sapota wine, whereas low pH stabilized the polyphenol content.

5.1.2.8 Alcohol content (%)

Wine prepared from banana varieties with pulp and water ratio of 1:2 had higher alcohol content than the wine prepared with 1:1 ratio of pulp and water. Wine from Karpooravalli with pulp and water ratio of 1:2 had the highest alcohol content (9.58 %) and the lowest (8.25 %) was in the wine from the variety Grand Naine with pulp and water ratio of 1:1.

Alcohol is the main factor which determines the beverages as alcoholic or nonalcoholic. The higher dilution of pulp may have facilitated efficient utilization of sugars by yeast for alcohol production during fermentation. Alcohol production of wine is due to the breakdown of sugars to alcohol by the yeast (Satave and Pethe, 2016). Ethanol is undoubtedly the most significant alcohol in wine and is the main organic fermentation by-product (Jackson, 2008). Ranjitha *et al.* (2015), also reported that banana juice diluted in 1:2 ratio had higher alcohol content in the wine as compared to 1:1 dilution.

5.1.2.9 Yeast population (cfu/ml)

Wine from all varieties did not differ significantly in the yeast population and it ranged from 11 to 12×10^6 cfu/ml. Banana wine prepared with pulp and water ratio of 1:1 had higher yeast population than the wine prepared with 1:2 ratio of pulp and water.

Higher dilution might have reduced the availability of total soluble solids in the must which resulted in lower population of yeast. Yeast cell count (cfu/ml) was done in wine prepared from banana and results were recorded on the 2nd, 4th, 6th and 8th day of must fermentation period. It was found that cell count increased from 4.5×10^7 to 5.0×10^7 on 4th day and got reduced to 4.8×10^7 on 8th day (Nwobodo, 2013). Nikhanj and Kocher (2011) reported that total yeast count of guava wine reduced from 1.2×10^5 to 1.2×10^1 during fermentation period.

5.1.2.10 Energy (kcal)

Wine from banana varieties prepared with pulp and water ratio of 1:1 had higher energy value than the wine prepared with 1:2 ratio of pulp and water. Wine from Palayankodan with pulp and water ratio of 1:1 had the highest energy value (29.84 kcal) and the lowest (21.70 kcal) was in the wine from the variety Yangambi with pulp and water ratio of 1:2. The energy value of wine is the combination of carbohydrate, fat and protein present in the wine. The greater dilution of pulp may have reduced the level of the constituents which resulted in lower energy value. Maksimovic and Maksimovic (2017) stated that the main nutritional value of wine comes from its high calorie content of ethanol. Fermentation leads to energy release with production of organic compounds (Jackson, 2008). Rai *et al.* (2010) reported that garcinia wine with higher level of reducing sugars resulted in high energy production.

5.1.2.11 Economics

Wine from the banana varieties incurred a cost of Rs of 129.6 for 1 litre of wine which was calculated by taking into account the cost of raw material, other inputs and labour charges. Wine from the pomegranate incurred a cost of Rs of 172 for 1 litre of wine which was calculated by taking into account the cost of raw material (pomegranate arils, man power, sugar and bottles), other inputs and labour charges (Ulla, 2011). Investigations carried out by Reddy and Reddy (2005), found that around 500 ml of juice can be produced from 1kg of Mango fruits. In order to produce 1250ml of juice it required 2.5kg of fruits. The processing cost was 40% of the raw material cost. The final cost of 1ltr mango wine was calculated and found to be Rs 35.

5.1.2.12 Wine yield

Banana wine prepared with pulp and water ratio of 1:2 had higher wine yield than the wine prepared with 1:1 ratio of pulp and water. Wine from Grand Naine with pulp and water ratio of 1:2 had the highest wine yield (79.0 %) and the lowest (40.0 %) was in the wine from the variety Poovan with pulp and water ratio of 1:1.

Pulp dilution influenced the recovery of wine, wherein higher dilution resulted in enhanced wine yield. The difference in the wine yield among the treatments may be due to differences in the composition of must and its subsequent fermentation by the yeast. Higher dilution of pulp led to higher wine recovery in sapota (Pawar, 2009). Waradai (2014) studied wine recovery (%) from blended wines made with different proportion of banana pulp and other fruit pulp (jamun, amla, papaya). The banana pulp alone gave the highest wine recovery (97.50%) when compared to other blended ratios of fruits.

5.2 QUALITY EVALUATION OF WINE DURING AGEING

5.2.1 Biochemical parameters

5.2.1.1 pH

The pH of wine showed an increasing trend during the ageing period. After 30 days of ageing, wine from Karpooravalli recorded the highest (3.83) pH and the lowest was recorded in wine from the variety Grand Naine (3.64). The wine prepared from Karpooravalli recorded the highest pH (3.85) and the lowest (3.69) was noticed in the wine from Yangambi, after 60 days of ageing.

Decrease in acidity may have resulted in the increase of pH during ageing. The development of esters from ethyl alcohol and volatile acids might have increased the pH. The increase in pH of wine during ageing from banana variety Robusta was reported by Shanmugasundaram *et al*. (2005) and in guava wine by Shankar *et al.* (2004).

5.2.1.2. Total soluble solids (^{0}Brix)

Total soluble solids of banana wine decreased throughout the ageing period. The wine from Karpooravalli recorded the highest TSS (4.72 ^{0}Brix) and the lowest (3.87 ^{0}Brix) was recorded in the wine from Poovan on 30th day of ageing. Similar trend followed after 60 days of ageing where in highest TSS (4.52 ^{0}Brix) was noticed in the wine from Karpooravalli and the lowest (3.65 ^{0}Brix) in wine prepared from Poovan.

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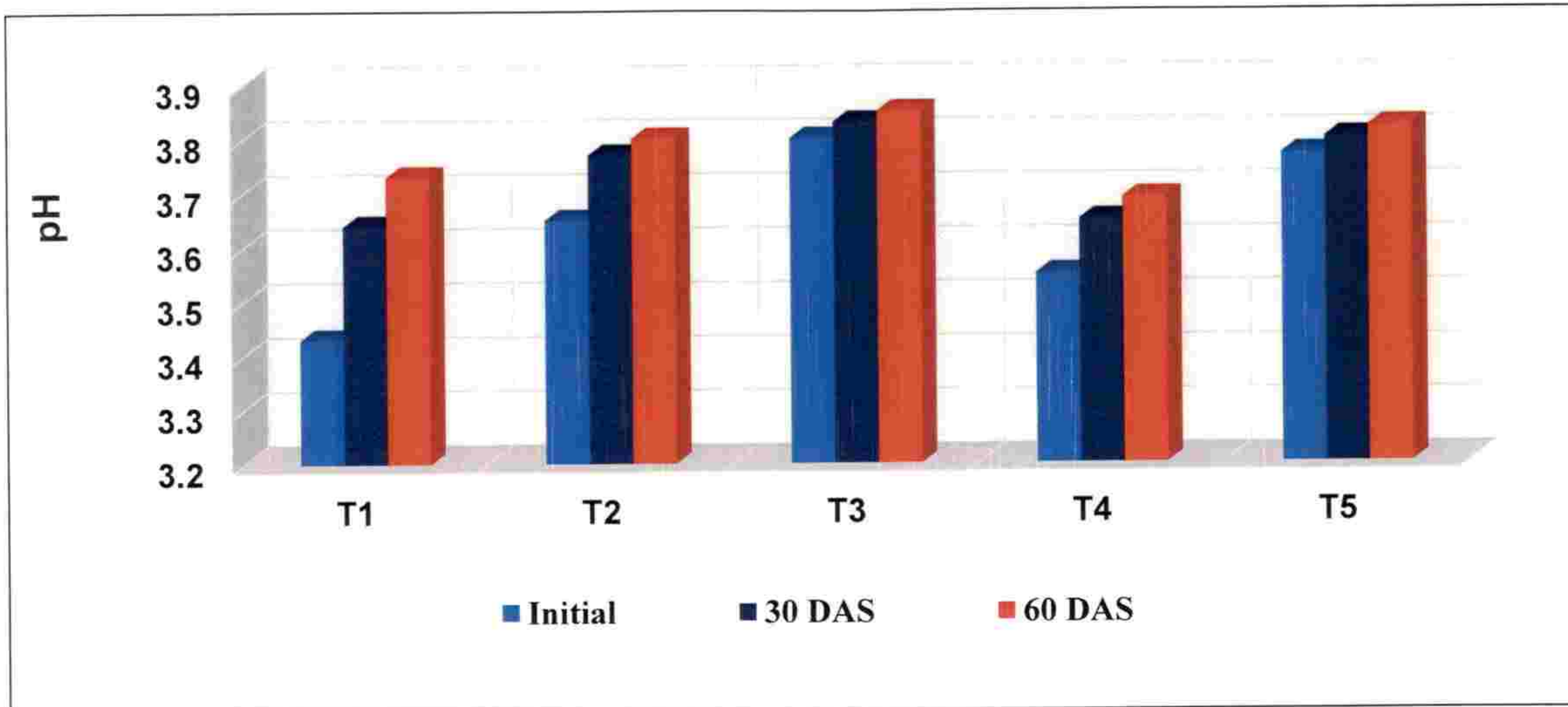

Figure 11: Effect of ageing on pH of banana wine

T1- Grand Naine banana wine

T2- Poovan banana wine

T3- Karpooravalli banana wine

T4- Yangambi (KM-5) banana wine

T5- Palayankodan banana wine

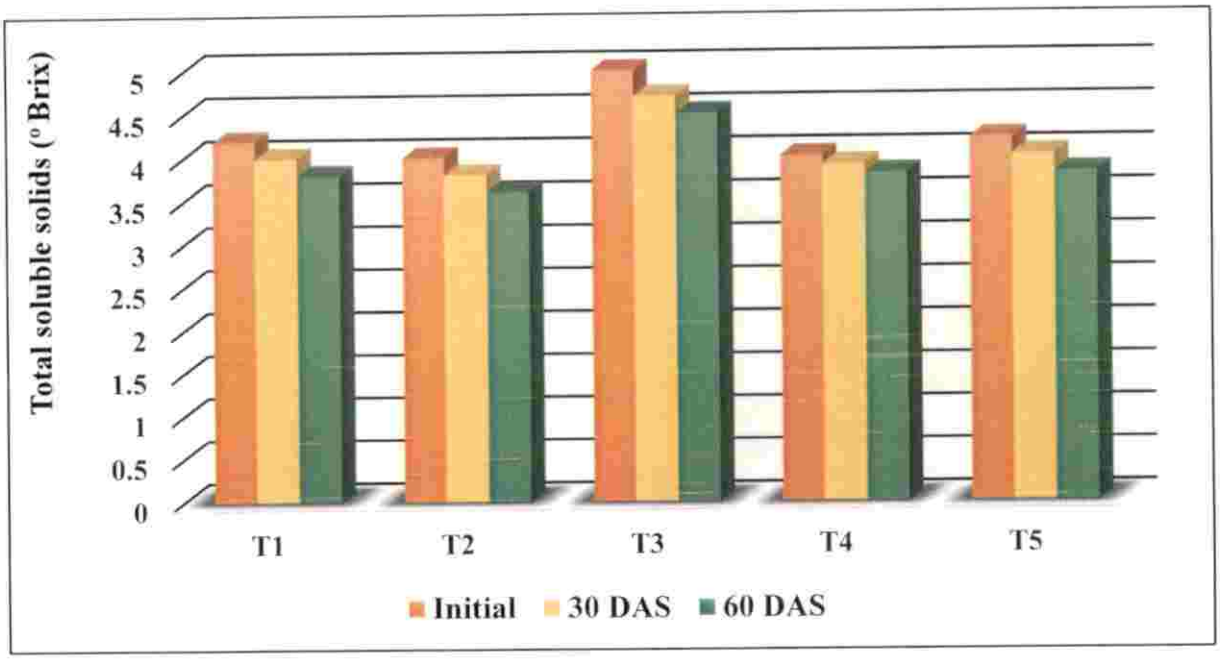

Figure 12: Effect of ageing on TSS (^{0}Brix) of banana wine

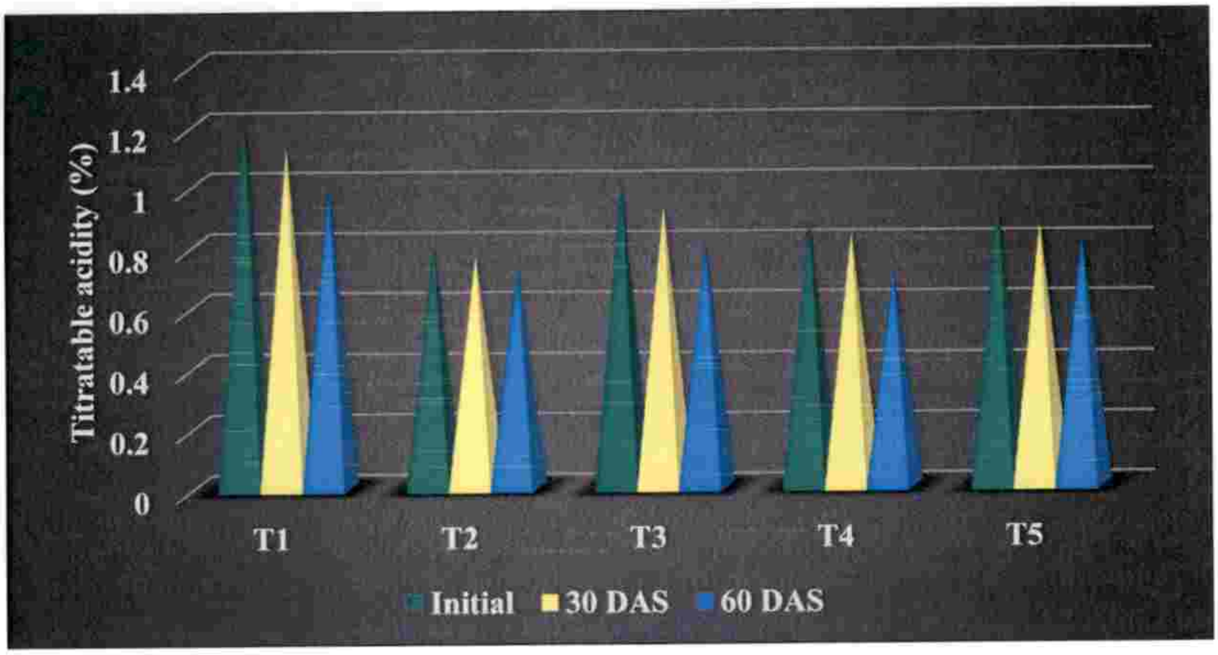

Figure 13: Effect of ageing on Titratable acidity (%) of banana wine

The drop in TSS during fermentation and subsequent ageing may be due to the transformation of sugars into alcohol. The decrease in TSS during ageing of wine may be due to the slower yeast activity that can still prevail during ageing, converting sugars into alcohol (Owen, 2004). Reduction of TSS during ageing was reported in jamun wine (Joshi *et al.*, 2012).

5.2.1.3 Titratable acidity (%)

Titratable acidity of banana wine decreased throughout the ageing period. The titratable acidity was highest in wine from Grand Naine (1.12%) and the lowest was recorded in wine produced from Poovan (0.76 %), after 30 days of ageing. After 60 days of ageing, wine from Grand Naine recorded the highest titratable acidity (1.00%) and the lowest was recorded in wine from Poovan (0.72 %).

Reduction in titratable acidity during ageing may be due to the precipitation of various acids into their respective salts (Amerine *et al.*, 1980). The reduction of titratable acidity during ageing is desirable which makes wine more acceptable (Zoecklein *et al.*, 2013). Wine prepared from mahua (*Madhuca longifolia)* showed decreasing trend of titratable acidity during ageing (Yadav *et al.*, 2009).

5.2.1.4 Reducing, non reducing and total sugars (%)

The reducing, non reducing and total sugars could not be detected in banana wine. It may be due to rapid fermentation by yeast and utilization of sugars for ethanol production.

Chowdary and Ray, (2007) reported that there was complete reduction of reducing sugars from 6.48% to 0.49% during fermentation of jamun wine. Similar reduction in sugars during ageing were also reported in guava wine (Nikhanj and Kocher, 2011).

5.2.1.5 Ascorbic acid (mg $100g^{-1}$)

The ascorbic acid content of banana wine showed a decreasing trend during ageing period (Table 19). After 30 days of ageing, wine from Poovan recorded the highest (1.99 mg $100g^{-1}$) ascorbic acid content and the lowest was recorded in wine from Grand Naine (1.65 mg $100g^{-1}$). The wine produced from Karpooravalli recorded the highest ascorbic acid (1.90mg $100g^{-1}$) and the lowest was noticed in wine from Yangambi and Grand Naine varieties (1.60 mg $100g^{-1}$) after 60 days of ageing.

Reduction in ascorbic acid content may be due to the oxidative reactions. (Nikhanj and Kocher, 2011) reported reduction in ascorbic acid content during the maturation of guava wine. Yadav *et a*l. (2009) also observed a decline in ascorbic acid content during ageing of mahua *(Madhuca longifolia*) wine.

5.2.1.6 Total phenols (mg $100g^{-1}$)

Total phenols of banana wine decreased throughout the ageing period. The wine prepared from Yangambi recorded the highest (73.25 mg $100g^{-1}$) phenol content and the lowest (52.00 mg $100g^{-1}$) was recorded in wine from Grand Naine, after 30 days of ageing. Similar trend followed after 60 days of ageing, where in highest phenols (56.25 mg $100g^{-1}$) was noticed in wine from Yangambi and the lowest (40.50 mg $100g^{-1}$) in wine from Grand Naine.

Reduction in phenol content of wine during ageing is due to breakdown of polyphenols to isoprenoid (Jackson, 2008). Decreasing trend of phenols during ageing was reported in jamun wine (Joshi *et al*., 2011) and guava wine (Nikhanj and Kocher, 2011).

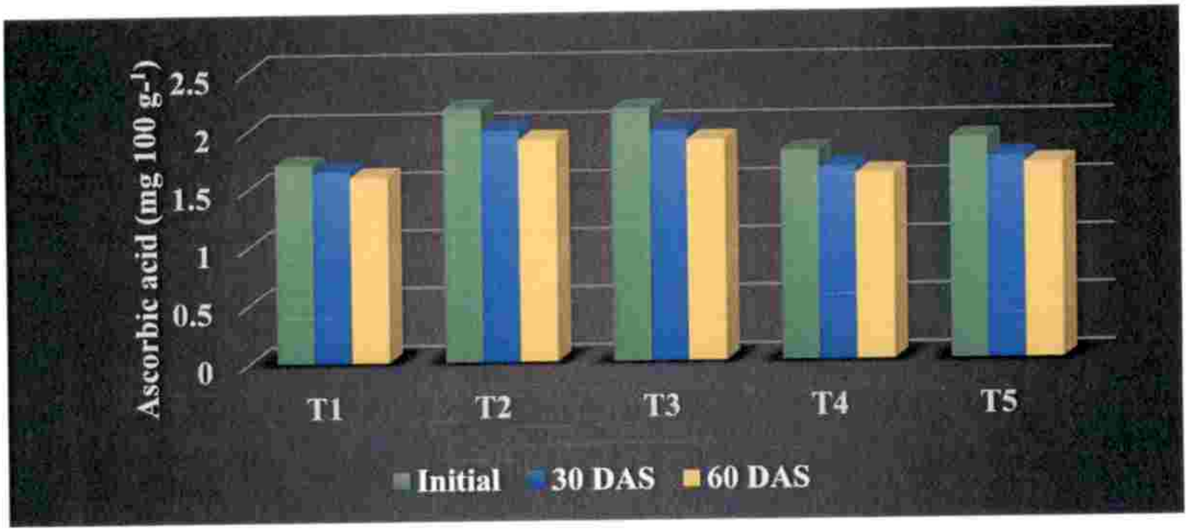

Figure 14: Effect of ageing on ascorbic acid content (mg 100 g^{-1}) of banana wine

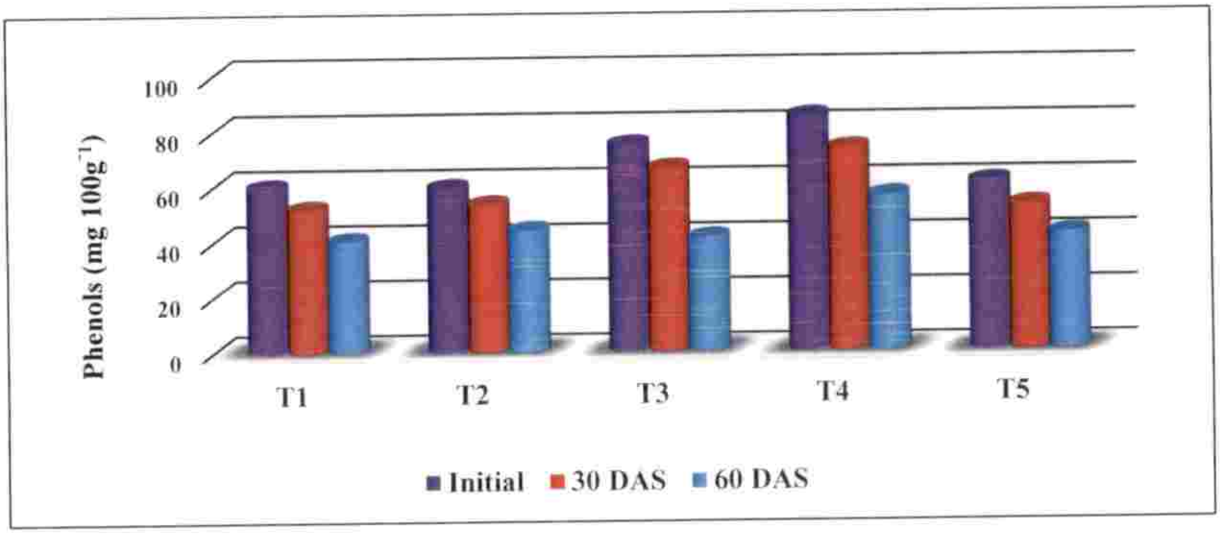

Figure 15: Effect of ageing on Phenols (mg 100 g^{-1}) of banana wine

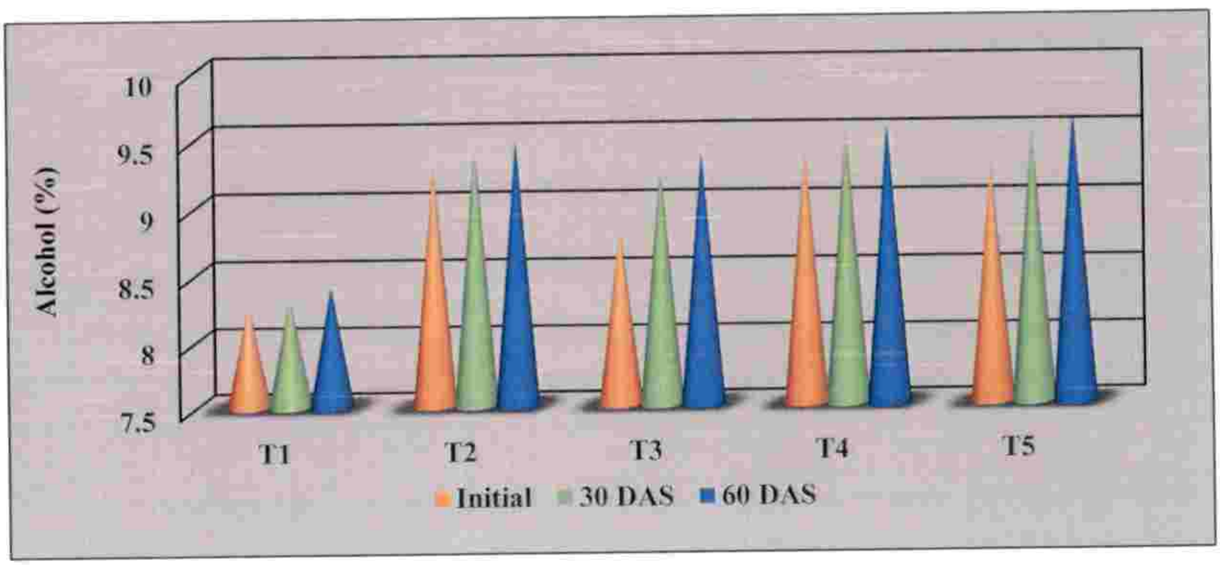

Figure 16: Effect of ageing on alcohol content (%) of banana wine

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5.2.1.7 Alcohol (%)

Alcohol content of wine prepared from all varieties of banana increased throughout the ageing period. Alcohol content was highest in wine prepared from Yangambi (9.56%) and lowest was recorded in wine from Grand Naine (8.33 %), after the 30 days of ageing. After 60 days of ageing, highest alcohol content (9.64%) was noticed in wine from Palayankodan and the lowest alcohol content was recorded in wine from Grand Naine (8.40 %).

Utilization of sugars by the yeast may have led to increase in the alcohol content of wine. (Holegar *et al.*, 2016), reported that during the maturation of jamun wine, alcohol content increased at monthly intervals. Gavimath *et al.* (2012) reported that alcohol content of banana wine rose to 15.49% after completion of ageing.

5.2.1.8 Flavour profile

Ethanol, ethyl hydrogen succinate and glycerin were common compounds that were detected in wine from all varieties. Phenyl ethyl alcohol was absent in Grand Naine whereas, it was present in all other wines. Wine from Grand Naine and Yangambi (KM-5) had similar compound methyltartronic acid. 1-Deoxy-d-arabitol in the wine from Karpooravalli, 1-Butanol-3-methyl (isoamyl alcohol) in the wine from Poovan and 3(p Hydroxyphenyl) 1propanol were the unique compounds detected in the wine from these varieties.

The major compounds detected during GCMSMS analysis of wines had pleasant aroma. The aroma descriptors of the compounds detected during analysis revealed that all these compounds were aromatically pleasing. The results showed that wines from all varieties had major compounds like Ethyl hydrogen succinate and Phenyl ethyl alcohol, two highly odorous compounds which may have given the wine delightful aroma.

Deng *et al.* (2016), reported that the major portion of composite wine of banana and orange was composed of alcohols and esters, which had the special, pleasant aroma. Ranjitha *et al.*, (2013) reported that during the fermentation of banana wine, there was detection of extremely odorous compounds such as methyl nonyl ketone and isoeuginol, 2 methoxy 4-vinyl phenol.

5.2.1.9 Sensory evaluation

Organoleptic evaluation of wine was done during monthly interval of ageing. After 30 days of ageing, wine prepared from Poovan had the highest overall acceptability score (7.6) and the lowest was found in the wine fromYangambi (5.6), whereas after the completion of ageing wine produced from Poovan had the highest overall acceptability score (7.6) and the lowest (5.9) was recorded in wine produced from the varieties Karpooravalli and Yangambi.

The flavour profile of wine from Yangambi revealed the presence of methyltartonic acid, which may have contributed to the unpleasant smell in this wine which is absent in the wine from Poovan. The higher overall acceptability score of wine from Poovan may be due to the unique flavouring compounds and lower titratable acidity which might have given it the distinct flavour properties.

Increase in sensory scores of wine during ageing may be because of the positive effects of the resultant biochemical reactions. Sharma and Joshi (2002), reported that sensory evaluation of strawberry wine done after the completion ageing, had higher scores when compared with scores of initiation of the ageing process. (Pawar, 2009) reported that sensory evaluation of sapota wine done after completion of ageing had higher scores when compared with scores of initiation of the ageing process.

5.2.1.10 Yeast population (cfu/ml)

Yeast population decreased during the ageing period. The wine from Palayankodan recorded the highest yeast population (8.25×10^3 cfu/ml) and the lowest was noticed in wine from Grand Naine and Yangambi (7.00×10^3 cfu/ml), after 1 month of ageing, whereas after the completion of ageing, wine prepared from Grand Naine had the highest yeast population (4.00×10^3 cfu/ml) and the lowest was noticed in wine from Palayankodan (3.25×10^3cfu/ml).

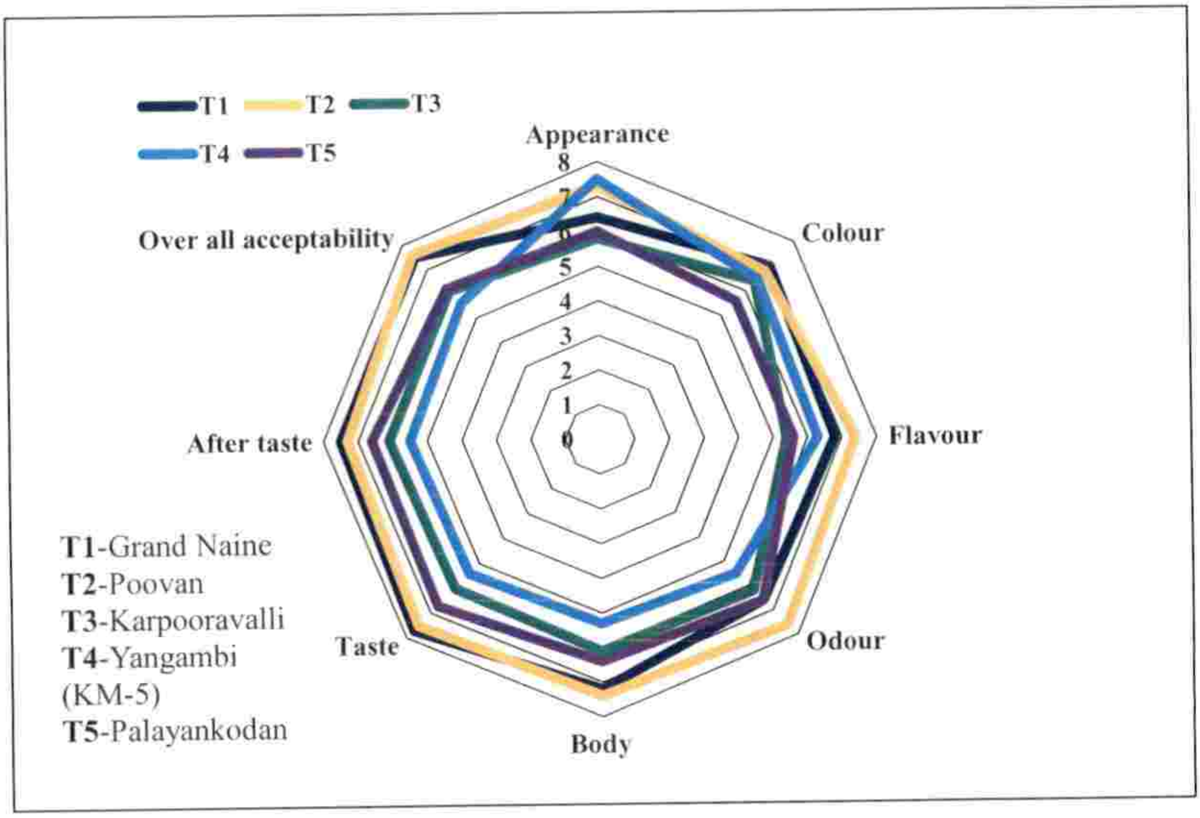

Figure 17: Effect of ageing (30 DAS) on sensory attributes of banana wine

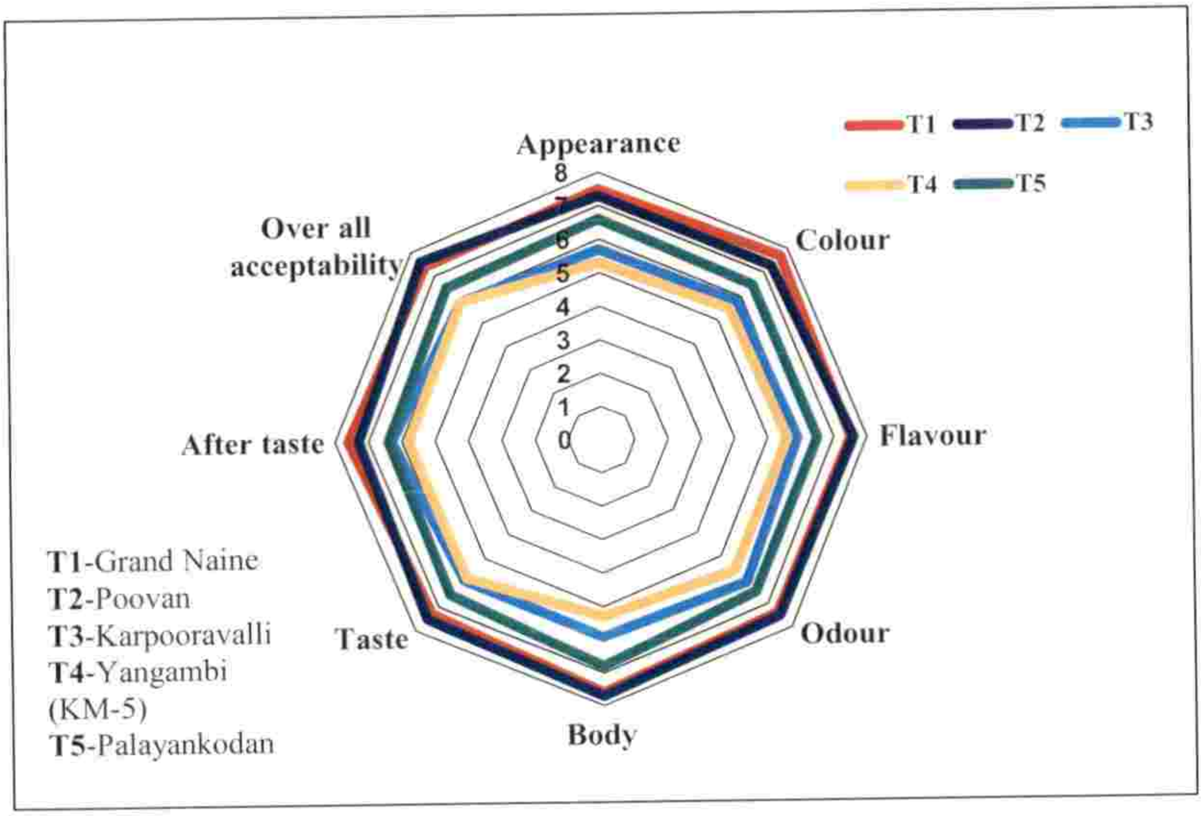

Figure 18: Effect of ageing (60 DAS) on sensory attributes of banana wine

Reduction in the yeast population may be due to decrease in the quantity of sugar available for further fermentation of wine. Increase in alcohol content of banana wine led to decrease in cell division of the yeast (Nwobodo, 2013). Nikhanj and Kocher (2011) reported that yeast population decreased during the ageing of guava wine.

5.2.1.11 Microbial population (cfu/ml)

After the 30 days of ageing, bacterial load of banana wine ranged from 0.75 to 1.50×10^3 cfu/ml. Finally, after the completion of ageing, all treatments showed negligible quantity of bacterial load. The fungal population decreased throughout the ageing period. After 30^{th} and 60^{th} days of ageing, wine from Karpooravalli had highest *Lactobacillus* population (0.50×10^4 cfu/ml) and the lowest (0.25×10^4 cfu/ml) was found in wine from (Grand Naine, Poovan, Yangambi and Palayankodan).

The changes in pH, increase in alcohol content and anaerobic environment may have led to reduction in total microbial count of wine. Sahu *et al*. (2012), reported that there was absence of bacteria, fungi and other spoilage microorganisms except *Saccharomyces cerevisiae* during the fermentation period of tendu (*Diospyros melanoxylon*) fruit wine. It was due to addition of KMS (Potassium meta bisulphite) which supressed the other spoilage microorganisms except *Saccharomyces cerevisiae* in grape wine (Winter *et al*., 2011).

5.3 QUALITY EVALUATION OF WINE DURING STORAGE

After two months of ageing, wine was transferred to bottles (amber coloured and plain) and stored under ambient conditions for

3 months. Observations were recorded at monthly intervals to observe the changes in quality during storage.

5.3.1 Biochemical parameters

5.3.1.1 pH

pH of all treatments showed an increase trend throughout storage. Wine stored in amber coloured bottles showed higher rate of increase compared to wine stored in plain bottles. After completion of storage, treatment T6 (wine from Karpooravalli stored in amber coloured bottles) recorded highest pH (3.91) and the lowest (3.75) was observed in T7 (wine from Yangambi (KM-5) stored in plain bottles).

Higher pH in wine stored in amber coloured bottles may be due to fall in acidity level in it. Production of hydrogen ions due to breakdown of the acids may have led to increase in the pH of wine. The rise in pH due to fall in the acidity may be due to precipitation of acids into salts. Increase in pH during storage of strawberry wine was reported by Sharma and Joshi, (2002). The increase in pH during storage of guava wine was reported by Shankar *et al.* (2004).

5.3.1.2 Total soluble solids (^{0} Brix)

Total soluble solids of banana wine decreased throughout the storage period of 3 months. Wine stored in plain bottles showed higher rate of decrease compared to wine stored in amber coloured bottles. After 3 months of storage, treatment T6 (wine from Karpooravalli stored in amber coloured bottles) recorded highest TSS (3.81 ^{0} Brix) and the treatment T3 (wine from Poovan stored in plain bottles) had the lowest (3.60 ^{0} Brix).

Decrease in TSS during storage of wine may be due to conversion of sugar into alcohol by yeast. Constant TSS values after two months of storage may be due to decline in the yeast population. Similar findings were reported in banana wine during storage which had no variation in TSS (Shanmugasundram *et al.*, 2005). Decreasing trend of TSS during storage was reported in jamun wine (Joshi *et al.*, 2011).

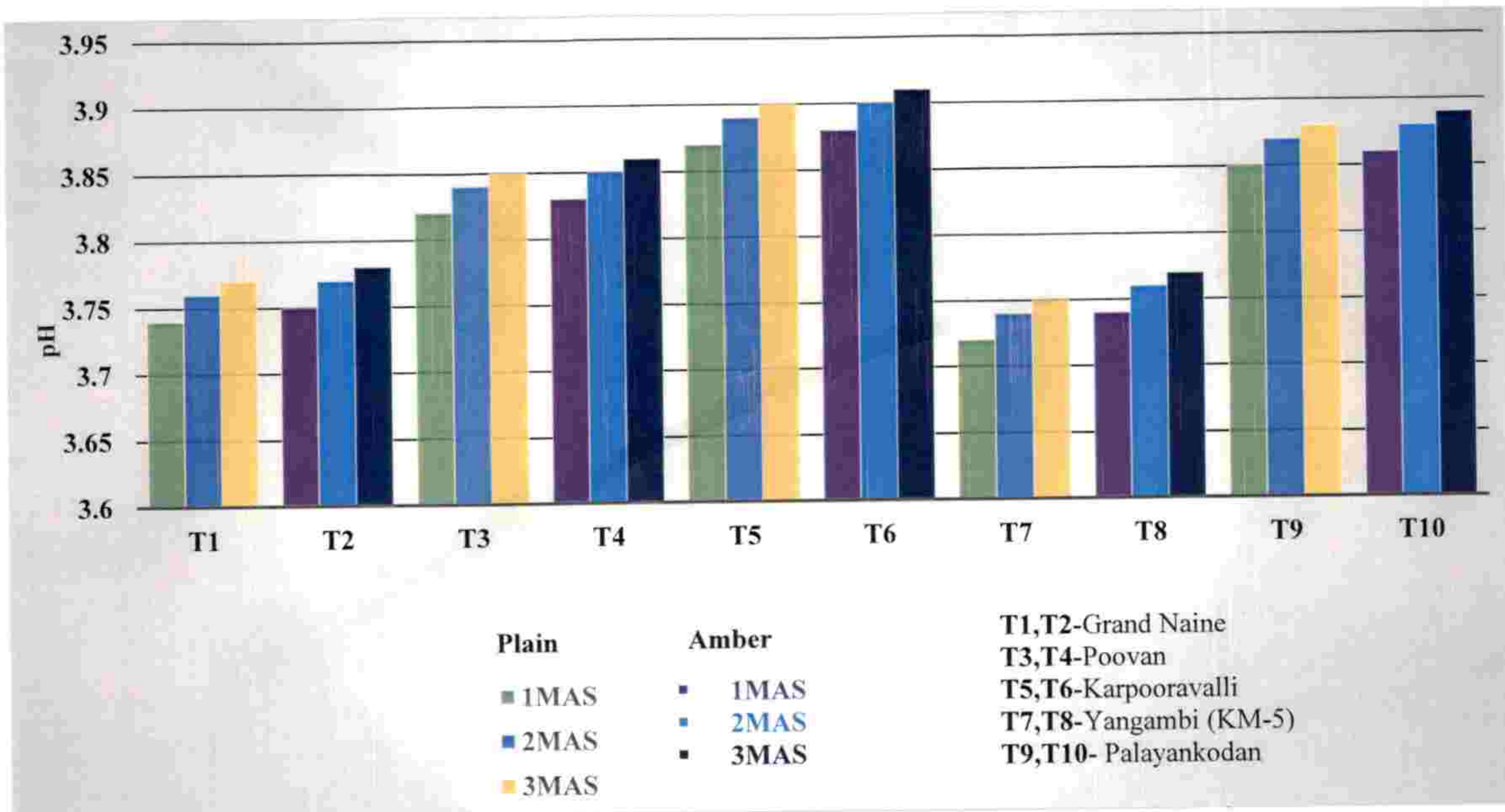

Figure 19: **Effect of storage on pH of banana wine**

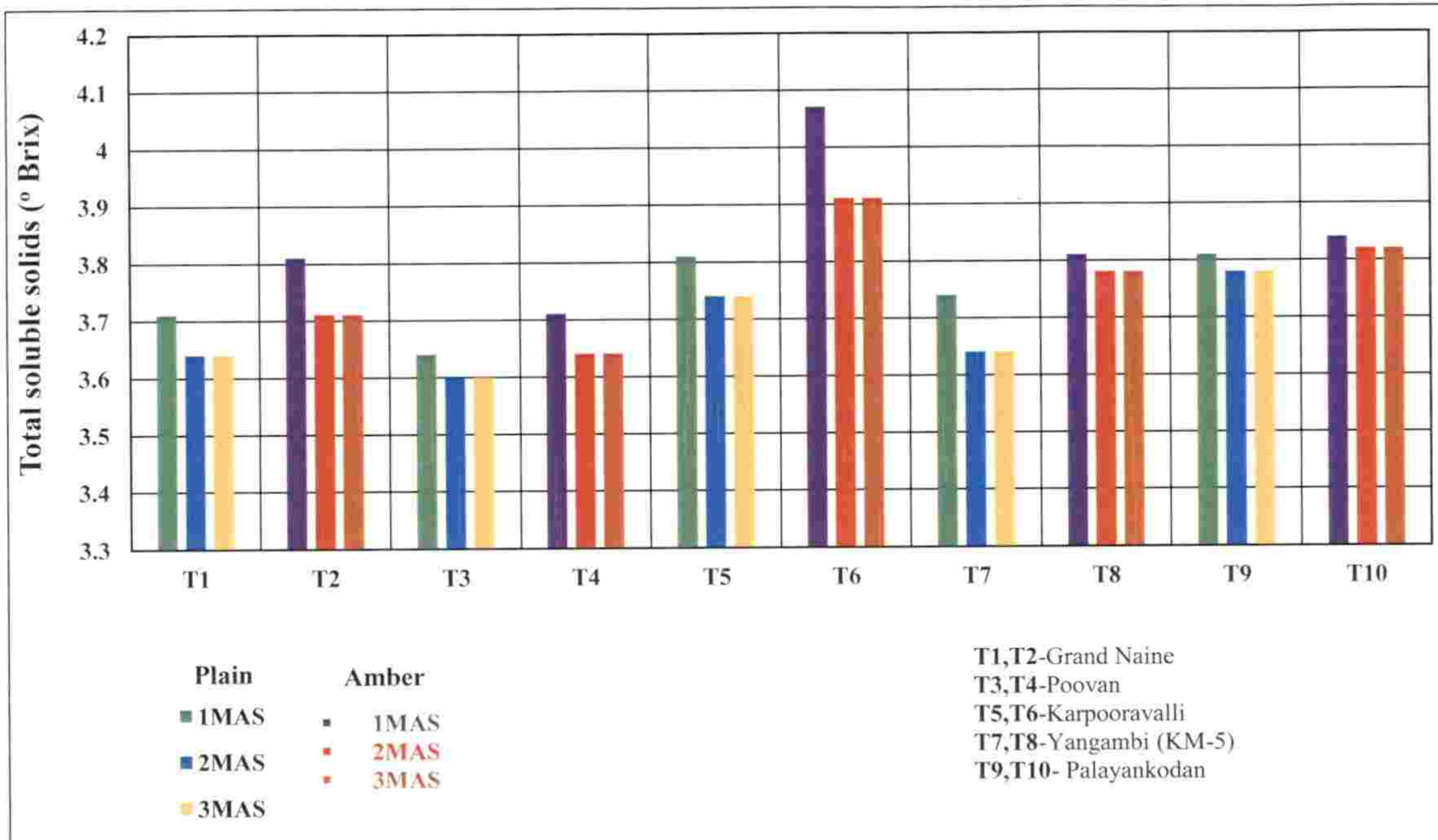

Figure 20: Effect of storage on TSS (^{0} Brix) of banana wine

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5.3.1.3 Titratable acidity (%)

Titratable acidity of banana wine showed a decreasing trend during storage. Wine stored in plain bottles showed higher rate of decrease compared to wine stored in amber coloured bottles. After 3 months of storage, treatment T2 (wine from Grand Naine stored in amber coloured bottles) recorded the highest (0.91 %) titratable acidity and the lowest was observed in T8 (wine from Yangambi (KM-5) stored in amber coloured bottles) (0.54 %).

Decline in titratable acidity may be due to precipitation of organic acids into their respective salts. Decrease in titratable acidity during storage of banana wine was reported by Jackson and Badrie, (2002). Similar findings were also reported during storage of banana wine by Shanmugasundram *et al.* (2005).

5.3.1.4 Reducing, non reducing and total sugars

Reducing, non reducing and total sugars were not detected during storage. Non detection of sugars may be due to breakdown of sugars for alcohol production by yeast during fermentation of wine and subsequent storage. Similar reduction in sugars during storage were also reported in guava wine (Nikhanj and Kocher, 2011). Sharma *et al.* (2004), reported that the concentration of reducing sugar decreased in jackfruit wine during storage from 19 to 1.05 percent.

5.3.1.5 Ascorbic acid (mg 100g-1)

Ascorbic of banana wine showed a decreasing trend during storage Wine stored in plain bottles showed higher rate of decrease compared to wine stored in amber coloured bottles. At the end of storage, treatment T10 (wine from Palayankodan stored in amber coloured bottles) recorded highest ascorbic acid (1.45 mg100g^{-1}) and the lowest (1.08 mg 100g^{-1}) was obtained in T1 (wine from Grand Naine stored in plain bottles).

Reduction in ascorbic acid content during storage may be due to oxidative reactions and maximum decline in ascorbic acid content in plain bottles may be due to higher rate of oxidative reactions in these bottles. The decreasing trend of ascorbic acid during storage was found in wine prepared from mahua *(Madhuca longifolia)* (Yadav *et al.,* 2009). Similar reduction in ascorbic acid was also observed in guava wine during storage (Nikhanj and Kocher, 2011).

5.3.1.6 Total phenols (mg 100g-1)

Phenol content in banana wine showed a decreasing trend during storage. Wine stored in plain bottles showed higher rate of decrease compared to wine stored in amber coloured bottles. At the end of storage, treatment T7 (wine from Yangambi stored in plain bottles) recorded highest phenols (33.5 mg100g^{-1}) and the lowest (25.5 mg 100g^{-1}) was obtained in T9 (wine from Palayankodan stored in plain bottles).

Reduction of total phenol content during the storage of wine may be due to loss of reactive hydroxyl groups due to oxidative reactions (Singleton *et al.,* 1999). Decreasing trend of phenols during storage was reported in jamun wine (Joshi et al., 2011) and also in guava wine (Nikhanj and Kocher, 2011).

5.3.1.7 Alcohol (%)

Alcohol content of banana wine revealed an increasing trend during storage. Wine stored in amber coloured bottles showed higher rate of increase compared to wine stored in plain bottles After 3 months of storage, treatment T10 (wine from Palayankodan stored in amber coloured bottles) recorded the highest alcohol content (9.85%) and the lowest (8.91 %) was in T1(wine from Grand Naine stored in plain bottles).

After 2 months of storage, alcohol production became stable due to non availability of sugars for the conversion and also due to declining population of yeast and similarly, there was no change in TSS after 2 months of storage. Nikhanj and Kocher (2011), reported that there were no changes in alcohol production due to absence of yeast colonies which stopped further fermentation of guava wine. Similar findings were reported in banana wine during storage which had no variation in alcohol content (Shanmugasundram *et al.,* 2005).

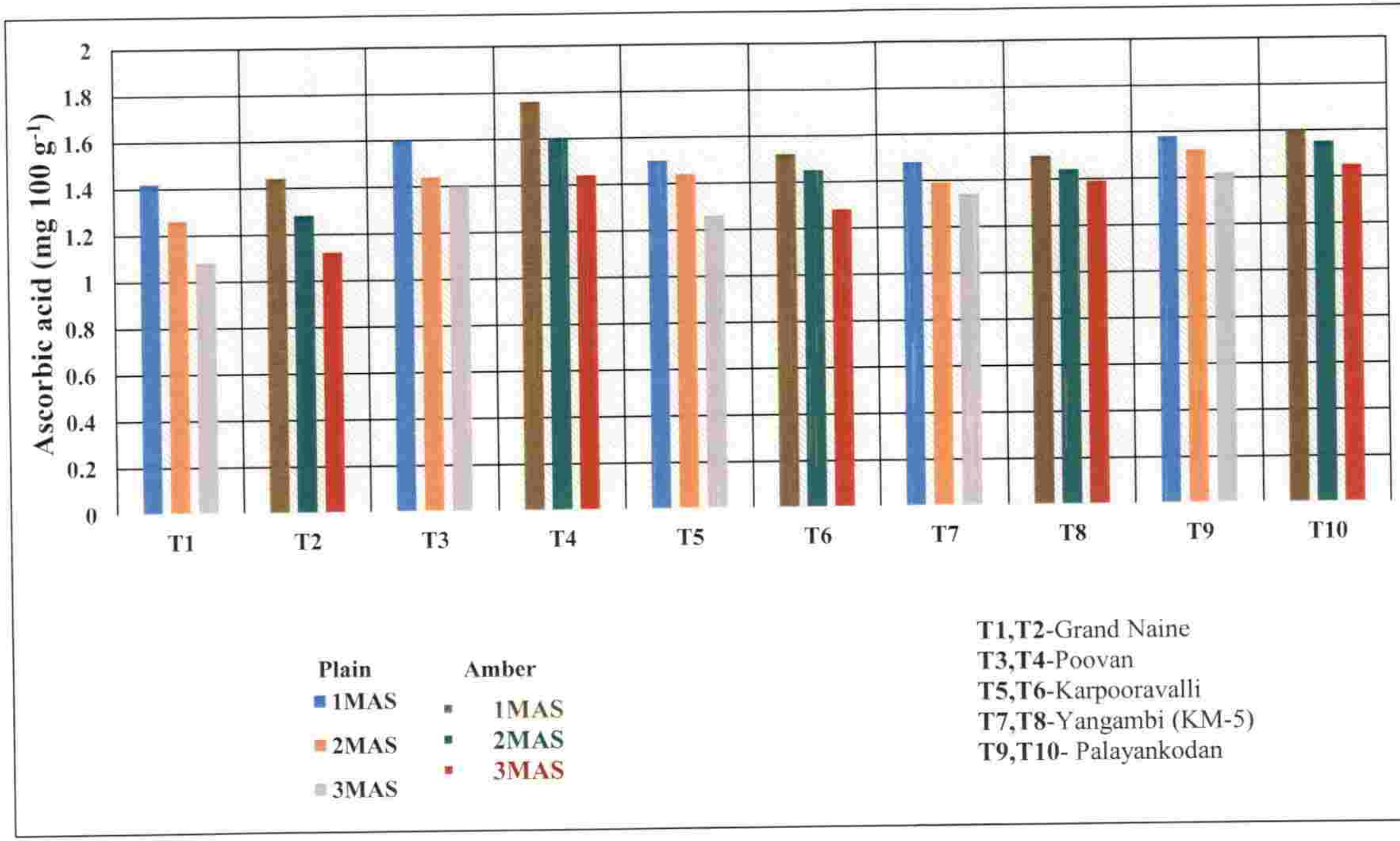

Figure 21: Effect of storage on ascorbic acid content (mg $100g^{-1}$) of banana wine

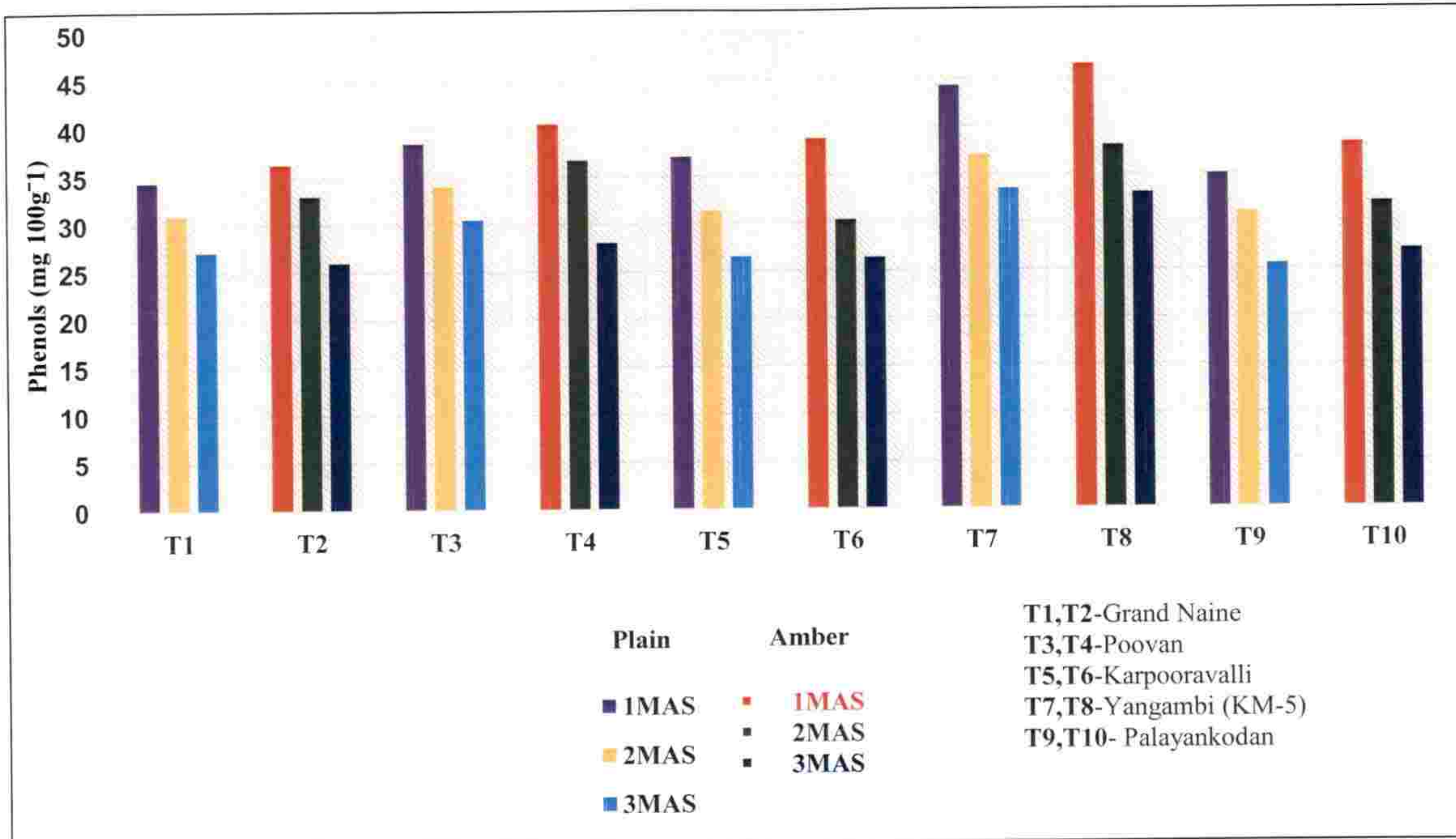

Figure 22: Effect of storage on phenol content (mg $100g^{-1}$) of banana wine

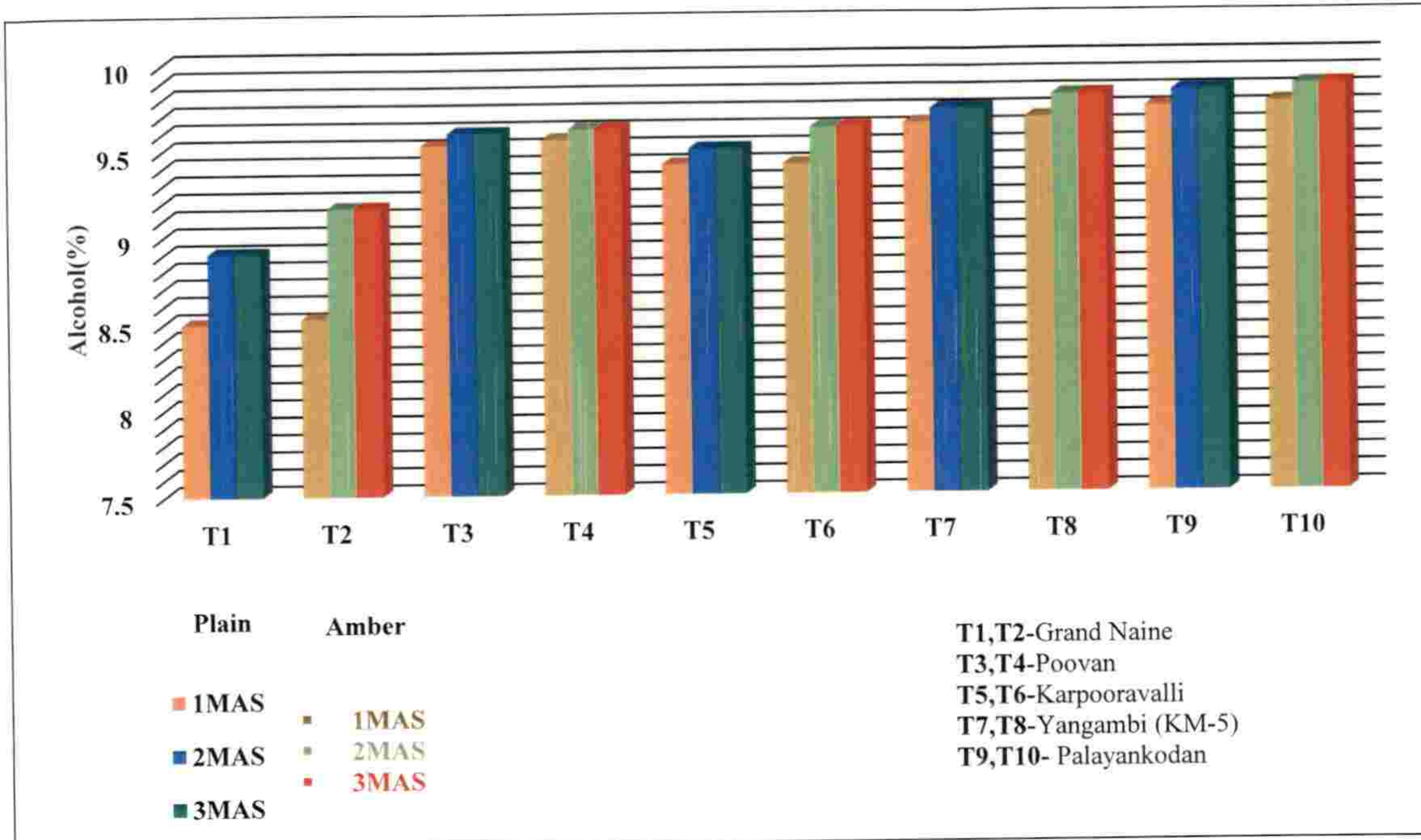

Figure 23: **Effect of storage on alcohol (%) of banana wine**

5.3.1.8 Sensory evaluation

After 30 days of storage, treatment T4 (wine from Poovan stored in amber coloured bottles) had highest overall acceptability score (7.6) and the lowest (5.6) was in T7 (wine from Yangambi stored in plain bottles). Treatment T4 (wine from Poovan stored in amber coloured bottles) had highest overall acceptability score (7.6) and the lowest (5.4) was in T7 (wine from Yangambi stored in plain bottles), after 2 months of storage. After 3 months of storage, treatment T4 (wine from Poovan stored in amber coloured bottles) had highest overall acceptability score (7.4) and the lowest (5.5) was in T7 (wine from Yangambi stored in plain bottles).

Superiority of wine from Poovan as compared to wine from other varieties may be due to its unique flavour, appropriate alcohol content and lower titratable acidity. Higher organoleptic scores for wine stored in amber coloured bottles may be due to lower rate of oxidative reactions which resulted in better flavour and colour. Selli *et al.*, (2002) stated that orange wine stored in bottles with more light penetration had higher oxidative reactions. (Moll, 1991) stated that bottles with less light penetration had lower undesirable changes during wine making and storage.

5.3.1.9 Yeast population (cfu/ml)

The yeast population was 0.3×10^3 cfu/ml in banana wine from various varieties after 1 month of storage. Thereafter, the yeast population declined and yeast could not be detected after 2nd and 3rd months of storage .The decline in yeast population during storage may be due to depletion of sugars, which serve as food for yeast. Similar decline in yeast population was also reported during storage of guava wine (Nikhanj and Kocher, 2011) and also in banana wine (Saritha, 2011).

5.3.1.10 Microbial population (cfu/ml)

Bacteria, fungi and *Lactobacillus* could not be detected during storage of banana wine. The changes in pH, increase in alcohol content and anaerobic environment might have led to reduction in microbial count of wine. Sahu *et al*. (2012), noted that during the fermentation period of tendu *(Diospyros melanoxylon*) fruit wine, there was no detection of bacteria, fungi and other spoilage microorganisms except *Saccharomyces cerevisiae*. (Saritha,2011) reported that during storage of banana wine there was no detection of bacterial and fungal population due to low pH and high alcohol content which led to decline in microbial population.

Summary

6. SUMMARY

The main objectives of the study were to evaluate quality of wine from different varieties of banana and to observe the changes in quality during storage. The experiment was carried out in the Department of Post Harvest Technology during 2017-19.

The different banana varieties (Grand Naine, Karpooravalli, Poovan, Yangambi (KM-5) and Palayankodan) were collected from various localities of Thrissur. The physico-chemical parameters of banana were evaluated. In the first experiment, wine was prepared from banana varieties with different dilutions of pulp and water. The nutritive and biochemical parameters of wine were evaluated. The organoleptic evaluation of wine revealed that wine prepared from the varieties Poovan, Grand Naine, Yangambi and Palayankodan in 1:2 ratio of pulp and water and the wine from Karpooravalli in 1:1 ratio of pulp and water were organoleptically superior. Wine from all five varieties in both the dilutions using pure culture of wine yeast (MTCC 4793) was organoleptically unacceptable as all the samples had an overall acceptability score less than 5.5.

The second experiment consisted of evaluating the changes in quality of wine during ageing in china clay jar for two months, followed by storage in plain and amber coloured bottles under ambient conditions for three months.

During ageing of wine, the pH and alcohol showed an increasing trend whereas titratable acidity, total soluble solids, ascorbic acid, phenols and microbial population showed a decreasing trend. Reducing, non reducing and total sugars could not be detected in the wine during ageing. The flavour profile analysis of wine revealed that ethanol, ethyl hydrogen succinate and glycerin were the major compounds in banana wine. Wine from Grand Naine contained a distinctive compound, methyl tartronic acid. The wine from Poovan also had compounds such as ethanol, ethyl hydrogen succinate, glycerin, phenyl ethyl alcohol and was distinctive from wine of the other varieties owing to the existence of a unique compound, 1-Butanol-3-methyl. The wine produced from Karpooravalli contained, a unique compound 1-Deoxy-d-arabitol in addition to ethanol, ethyl hydrogen succinate, glycerin and phenyl ethyl alcohol. Similar to the wine from the variety Grand Naine, the wine produced from Yangambi contained methyl tratronic acid in addition to other compounds like ethanol, ethyl hydrogen succinate, glycerin and phenyl ethyl alcohol. The wine made from Palayankodan had compounds such as ethanol, ethyl hydrogen succinate, glycerin, phenyl ethyl alcohol and was distinctive from wine of the other varieties owing to the existence of a distinctive compound 3(p Hydroxyphenyl)1propanol.

After completion of ageing, wine from the variety Poovan had the highest organoleptic score (7.6),which had an alcohol content of 9.47%, pH(3.8), total soluble solids(3.6 ^{0}Brix), ascorbic acid (1.99 mg 100 g-^{1}), total phenols(44.25 mg 100 g-^{1}) and titratable acidity of 0.72% .

Banana wine, after ageing was stored in plain and amber coloured bottles under ambient conditions, for three months. After one month of storage, pH and alcohol content showed an increasing trend whereas titratable acidity, total soluble solids, ascorbic acid, total phenols and microbial population showed a decreasing trend. Reducing, non reducing and total sugars could not be detected in the wine. Same trend continued even after two months of storage. At the end the of storage period, the total soluble solids and alcohol content remained stable without showing any variation in their values as that of the previous month whereas pH showed an increasing trend.

Titratable acidity, ascorbic acid, phenols and microbial population showed a decreasing trend. Colour retention was better in amber coloured bottles. Wine from the variety Poovan had the highest overall acceptability score throughout the storage period. Cost involved in the production of 1 litre of wine was Rs. 129 to 144.

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Appendices

APPENDIX – I

Score card for organoleptic evaluation of wine from banana

Name of the judge:
Date:

Characteristics	Score						
	T1	T2	T3	T4	T5	T6	T7
Appearance							
Colour							
Flavour							
Body							
Odour							
Taste							
After taste							
Overall acceptability							

9 point Hedonic scale

Like extremely	9
Like very much	8
Like moderately	7
Like slightly	6
Neither like nor dislike	5
Dislike slightly	4
Dislike moderately	3
Dislike very much	2
Dislike extremely	1

Signature:

APPENDIX II

MEDIA COMPOSITION

1. **NUTRIENT AGAR MEDIA** (FOR BACTERIA)

Beef extract	: 3 g
Peptone	: 5 g
Sodium chloride	: 5 g
Agar	: 18 g
Distilled water	: 1000 ml
pH	: 6.8-7.2

2. **MARTIN ROSE BENGAL AGAR** (FOR FUNGUS)

Glucose	: 10g
Peptone	: 5 g
KH_2PO_4	: 1 g
$MgSO_4\ 7H_2O$	: 0.5 g
Rose Bengal	: 0.035 g
Agar	: 18 g
Distilled water	: 1000 ml

3. **SABOURAUD DEXTROSE AGAR MEDIA** (FOR YEAST)

Dextrose	: 40 g
Mycological, peptone	: 10 g
Agar	: 15 g
Final pH	: 5.6 ± 0.2
Distilled water	: 1000 ml

APPENDIX III

A. Mean rank scores of banana wine using Baker's yeast

Treatments	Ratio of pulp and water	Appearance	Colour	Flavour	Odour	Body	Taste	After taste	Over all acceptability
T1	1:1	1.15	1.35	1.28	1.65	1.25	1.35	1.5	1.25
	1:2	1.85	1.65	1.72	1.35	1.75	1.65	1.5	1.75
Kendal's W test		**0.544**	**0.129**	**0.296**	**0.18**	**0.5**	**0.18**	**0**	**0.357**
T2	1:1	1.15	1	1.35	1.35	1.3	1.25	1.35	1.2
	1:2	1.85	2	1.65	1.65	1.7	1.75	1.65	1.8
Kendal's W test		**0.7**	**1.0**	**0.18**	**0.18**	**0.4**	**0.5**	**0.18**	**0.6**
T3	1:1	1.45	1.65	1.85	1.70	1.65	1.90	1.70	1.70
	1:2	1.55	1.35	1.15	1.30	1.35	1.10	1.30	1.30
Kendal's W test		**0.02**	**0.3**	**0.544**	**0.3**	**0.129**	**0.64**	**0.4**	**0.4**
T4	1:1	1.15	1.20	1.20	1.65	1.20	1.35	1.5	1.25
	1:2	1.85	1.80	1.80	1.35	1.80	1.65	1.5	1.75
Kendal's W test		**0.7**	**0.6**	**0.6**	**0.18**	**0.6**	**0.18**	**0**	**0.357**
T5	1:1	1.35	1.45	1.20	1.40	1.40	1.25	1.45	1.30
	1:2	1.65	1.55	1.80	1.60	1.60	1.75	1.55	1.70
Kendal's W test		**0.18**	**0.033**	**0.45**	**0.1**	**0.67**	**0.357**	**0.014**	**0.2**

B. Mean rank scores of banana wine using of banana wine using pure strain (MTCC 4793)

Treatments	Ratio of pulp and water	Appearance	Colour	Flavour	Odour	Body	Taste	After taste	Over all acceptability
T6	1:1	1.40	1.69	1.55	1.35	1.50	1.55	1.60	1.60
	1:2	1.60	1.31	1.45	1.65	1.45	1.45	1.40	1.40
Kendal's W test		**0.067**	**0.225**	**0.02**	**0**	**0.014**	**0.014**	**0**	**0.067**
T7	1:1	1.55	1.60	1.60	1.45	1.55	1.40	1.45	1.30
	1:2	1.45	1.40	1.40	1.55	1.45	1.60	1.55	1.70
Kendal's W test		**0.02**	**0.067**	**0.1**	**0.02**	**0.02**	**0.067**	**0.033**	**0.139**
T8	1:1	1.35	1.45	1.55	1.55	1.65	1.35	1.55	1.40
	1:2	1.65	1.55	1.45	1.45	1.35	1.65	1.45	1.60
Kendal's W test		**0.129**	**0.014**	**0.033**	**0.02**	**0.129**	**0.18**	**0.033**	**0.1**
T9	1:1	1.70	1.40	1.55	1.50	1.60	1.60	1.50	1.60
	1:2	1.30	1.60	1.45	1.50	1.40	1.40	1.50	1.40
Kendal's W test		**0.267**	**0.067**	**0.02**	**0**	**0.067**	**0.067**	**0**	**0.067**
T10	1:1	1.35	1.45	1.55	1.55	1.65	1.35	1.55	1.60
	1:2	1.65	1.55	1.45	1.45	1.35	1.65	1.45	1.40
Kendal's W test		**0.129**	**0.220**	**0.067**	**0.014**	**0.02**	**0.014**	**0**	**0.014**

C. Mean rank scores for banana wine kept for ageing (30DAS)

Treatments	Appearance	Colour	Flavour	Odour	Body	Taste	After taste	Over all acceptability
T1	2.5	3.75	3.9	3.15	3.95	4.4	4.35	4.35
T2	4.05	3.45	4.65	4.7	4.35	4.15	4.05	4.5
T3	1.75	2.85	1.55	2.5	2.5	2.15	2.35	2.2
T4	4.5	3.3	2.95	1.4	1.45	1.35	1.4	1.65
T5	2.2	1.65	1.95	3.25	2.75	2.95	2.85	2.3
Kendal's W test	0.708	0.329	0.817	0.677	0.676	0.787	0.678	0.789

D. Mean rank scores of banana wine kept for ageing (60DAS)

Treatments	Appearance	Colour	Flavour	Odour	Body	Taste	After taste	Over all acceptability
T1	4.4	4.65	4.4	4.1	4.35	3.95	4.55	4.1
T2	4.2	3.95	4.5	4.35	4.4	4.45	3.95	4.35
T3	1.9	1.95	1.95	2.2	1.95	1.9	2.4	1.85
T4	1.4	1.5	1.75	1.65	1.35	1.85	1.6	1.95
T5	3.1	2.95	2.4	2.7	2.95	2.85	2.5	2.75
Kendal's W test	0.816	0.789	0.827	0.703	0.865	0.67	0.744	0.681

E. Mean rank scores of banana wine kept for storage (1MAS)

Treatments	Appearance	Colour	Flavour	Odour	Body	Taste	After taste	Over all acceptability
T1	6.25	4.6	5.8	5.05	5	6.9	5.55	6.2
T2	6.85	6.7	6.8	7.1	5.2	6.8	8.25	7.85
T3	6.15	5.75	6	5.7	6.5	5.7	4.85	5.25
T4	8.90	8.75	8.65	8.55	9	8.75	9	8.7
T5	3.25	2.9	3.6	4.65	3	4.4	4.55	2.85
T6	5.25	5.5	5.6	5.6	5.3	5.6	5.6	5.9
T7	2.70	2.55	2.45	2	2.55	2.25	2.2	2.55
T8	3.55	4.1	3.8	4.1	5.35	4.25	3.2	4.55
T9	5.85	6.95	5.6	5.5	6.5	4.85	5.55	5.05
T10	6.25	7.2	6.9	6.75	6.6	5.5	6.25	6.1
Kendal's W test	0.467	0.504	0.417	0.412	0.452	0.406	0.55	.480

F. Mean rank scores of banana wine kept for storage (2MAS)

Treatments	Appearance	Colour	Flavour	Odour	Body	Taste	After taste	Over all acceptability
T1	6.15	4.8	5.45	5.85	5.8	4.6	6.1	6.6
T2	5.95	6.5	8.15	7.4	6.55	8.15	6.35	5.85
T3	5.35	4.3	6.35	5.1	5.9	6.05	5.25	5.25
T4	8.55	9.2	8.6	9.05	8.95	8.85	8.8	9.1
T5	4.25	4.3	4.55	5	3.3	4.9	2.85	4.2
T6	5.45	5.9	4.7	4.75	5.75	5.55	5.9	6.15
T7	2.3	2.55	1.95	2.6	2.85	1.15	2.9	2.2
T8	4.5	5.25	4.6	3.4	4.45	3.65	4.25	4.4
T9	5.9	5.95	5.1	5.15	5.15	4.6	5.9	5.45
T10	6.6	6.25	5.55	6.7	6.3	7.5	6.7	5.8
Kendal's W test	0.36	0.412	0.461	0.443	0.396	0.658	0.424	0.435

G. Mean rank scores of banana wine kept for storage (3MAS)

Treatments	Appearance	Colour	Flavour	Odour	Body	Taste	After taste	Over all acceptability
T1	5.7	5.55	6.2	5.8	5.8	6.3	4.95	5.65
T2	7.05	7.7	7.1	6.8	7.85	5.75	6.85	7.4
T3	6.1	5.6	5.2	5.45	4.7	6.25	4.9	6.1
T4	8.9	8.65	9	9.45	8.65	8.15	8.7	8.4
T5	4.15	4.65	2.8	4.1	3.55	3.8	4.4	3.75
T6	5.7	4.85	5.5	4.8	5.1	6.55	5.2	4.35
T7	2.6	2.15	2.2	2.8	1.75	2.3	3.4	2.3
T8	3.4	3.95	4.7	4.8	4.35	3.45	5.6	3.8
T9	4.5	5.15	6.05	4.25	6.2	6.7	5.1	6.3
T10	6.9	6.75	6.25	6.75	7.05	5.75	5.9	6.95
Kendal's W test	0.483	0.438	0.531	0.444	0.538	0.429	0.282	0.467

PROCESS STANDARDISATION AND QUALITY EVALUATION OF WINE FROM BANANA

(*Musa spp.*)

By

SARTHAK KIRIBHAGA

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ABSTRACT OF THE THESIS

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DEPARTMENT OF POST HARVEST TECHNOLOGY

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ABSTRACT

Banana is one of the economically important fruit crops of Kerala. It is highly perishable in nature because of textural characteristics and high moisture content. Post harvest losses of banana can be reduced by adopting proper post harvest management practices and processing into value added products.

Banana wine is a delicious alcoholic beverage with low alcohol content. The cost of production of banana based alcoholic beverages is much cheaper than other fruit based beverages. Hence, the present study is aimed at evaluating the popular banana varieties of Kerala for wine production and to evaluate the quality of wine during storage. The experiment was carried out in the Department of Post Harvest Technology during 2017-19.

The different banana varieties (Grand Naine, Karpooravalli, Poovan, Yangambi (KM-5) and Palayankodan) were collected from various localities of Thrissur. The physico-chemical parameters of ripe banana were evaluated before preparation of wine. Wine was prepared from banana varieties with 1:1 and 1:2 dilutions of pulp and water. The nutritive, biochemical and organoleptic properties of wine were determined. Organoleptic evaluation of wine revealed that wine prepared from the varieties Poovan, Grand Naine, Yangambi and Palayankodan in 1:2 ratio of pulp and water and the wine from Karpooravalli in 1:1 ratio of pulp and water were superior. Wine from all five varieties in both the dilutions using pure culture of wine yeast (MTCC 4793) was organoleptically unacceptable as all the samples had an overall acceptability score less than 5.5.

The wine with maximum scores from each variety was selected and kept for ageing in china clay jar for two months, followed by storage in plain and amber coloured bottles under ambient conditions for three months. Changes in quality of wine during ageing and subsequent storage were assessed.

During ageing of wine, the pH and alcohol showed an increasing trend whereas titratable acidity, total soluble solids, ascorbic acid, phenols and microbial population showed a decreasing trend. Reducing, non reducing and total sugars

could not be detected in the wine during ageing. The flavour profile analysis of wine revealed that ethanol, ethyl hydrogen succinate and glycerin were the major compounds in banana wine. Wine from Grand Naine contained a distinctive compound, methyl tratronic acid. The wine from Poovan also had compounds such as ethanol, ethyl hydrogen succinate, glycerin, phenyl ethyl alcohol and was distinctive from the wine of other varieties owing to the existence of a unique compound, 1-Butanol-3-methyl. The wine produced from Karpooravalli contained a unique compound, 1-Deoxy-d-arabitol in addition to ethanol, ethyl hydrogen succinate, glycerin and phenyl ethyl alcohol. Similar to the wine from the variety Grand Naine, the wine produced from Yangambi contained methyltratronic acid in addition to other compounds like ethanol, ethyl hydrogen succinate, glycerin and phenyl ethyl alcohol. The wine made from Palayankodan was distinctive from the wine of other varieties owing to the existence of a distinctive compound, 3(p Hydroxyphenyl) 1propanol.

After completion of ageing, wine from the variety Poovan had the highest organoleptic score (7.6),which had an alcohol content of 9.47%, pH(3.8), total soluble solids(3.6 ^{0}Brix), ascorbic acid (1.99 mg 100 g-^{1}), total phenols(44.25 mg 100 g-^{1}) and titratable acidity of 0.72%.

Banana wine, after ageing was stored in plain and amber coloured bottles under ambient conditions for three months. After one month of storage, pH and alcohol content showed an increasing trend whereas titratable acidity, total soluble solids, ascorbic acid, total phenols and microbial population showed a decreasing trend. Reducing, non reducing and total sugars could not be detected in the wine. Same trend continued even after two months of storage. At the end of storage period, the total soluble solids and alcohol content remained stable without showing any variation in their values as that of the previous month whereas pH showed an increasing trend. Titratable acidity, ascorbic acid, phenols and microbial population showed a decreasing trend. Colour retention was better in amber coloured bottles. Wine from the variety Poovan had the highest overall acceptability score throughout the storage period. Cost involved in the production of 1 litre of wine ranged from Rs. 129 to 144.