PROCESS STANDARDISATION FOR BANANA WINE

By

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THESIS

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DECLARATION

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

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DEDICATED TO MY FAMILY
AND
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ABBREVIATIONS

BY – Baker's yeast

cfu – Colony forming unit

g – Gram

IMTECH – Institute of Microbial Technology

kg – Kilogram

KMS – Potassium metabisulphite

L – Litre

mg – Milligram

ml – Millilitre

MTCC – Microbial Type Culture Collection and gene bank

PCS – Pressure cooked substrate

pH - Potentiel d'Hydrogene

PS – Pure strain

TSS – Total soluble solids

INTRODUCTION

1. INTRODUCTION

Banana, one of the earliest crops cultivated by man, remains to be one of the most important fruit crops, especially of the tropics. The term 'banana' was introduced from the Guinea Coast of the West Africa by the Portugese, while the term 'plantain' (for cooking bananas) was derived from 'plantano' of the Spaniards. But, generally the term 'banana' includes all edible varieties eaten as ripe fruits or as cooked food. There are hundreds of varieties of banana growing in different parts of the world. In Kerala, there are about 50 cultivars of banana, which form one of the most important items in our diet. *Palayankodan, Kunnaan, Ethan or Nenthran*, Morris or Robusta, *Poovan, Kappa vazha* (red banana) and *Monthan* are few cultivars of banana in Kerala.

Banana has great nutritional significance. It has a rare combination of energy value, tissue building elements, vitamins and minerals. It is rich in different minerals and components like β carotene, vitamin B_6, vitamin C and potassium. It is a good source of calories since it is rich in sugars compared to any other fresh fruit. The use of bananas has been found beneficial in the treatment of several medical conditions such as intestinal disorders, constipation, arthritis, gout, anaemia, allergies, kidney stones, tuberculosis and urinary disorders.

The shelf-life of banana is short under the prevailing temperature and humidity conditions in tropical countries. Following maturity and harvest, there is a rapid rate of deterioration of ripe banana. Though consumed to a considerable extent, large quantities of ripe bananas are usually wasted as a result of poor handling and inadequate storage facilities. Farmers are often faced with the problem of excess production of bananas resulting in spoilage, wastage of fruits and lower returns. Tremendous quantities of bananas are lost either through over production and / or in sorting and grading to meet quality standards for the fresh fruit export market, which could otherwise be used for processing. Having to compete in a global market, banana producers are increasingly being faced with competition for the fresh fruits. Therefore it is imperative that the fruit processing industries diverse their markets in processed products, thus giving added value to the fresh fruits.

A wide range of products can be processed from banana. Among the products highlighted are puree, juice, flour, jam, powder, vinegar, confectionery jelly, pectin and banana bread which have wide commercialization. Wine is also prepared from ripe banana. According to Kordylas (1990), the peel and pulp of ripe bananas contain appreciable amounts of fermentable sugars, which can be used for alcoholic fermentation.

Wine is a beverage resulting from fermentation of fruit juice by yeast with proper processing and additives. It can be classified as appetizer, red table wines, white table wines, dessert wines and sparkling wine. Highly acceptable wines can be made from all fruits. Wine is unique among beverages in that it contains both alcohol and antioxidants. Antioxidants protect the body systems from degeneration and prevent diseases such as diabetes, heart diseases and cancer. Besides antioxidants, wines also contain all the nutritional constituents of the fruit juice because it is not subjected to any heat treatment. Due to their low alcohol content, they do not cause any severe intoxication. Instead, they help in the preservation of the otherwise perishable fruits by its low alcohol content. In this context, methods for preparation of quality wine from banana, a perishable commodity would help farmers to increase their income from banana.

Fermenting banana juice is considered to be an attractive means of utilising surplus and overripe bananas. Even though preparation of banana wine has been tried by many workers earlier, a standardized technique that can be adopted by farmers at household level is not common. Hence, the present study entitled 'Process standardisation for banana wine' has been undertaken with the following objectives

1. Standardisation of banana wine with pure strains of wine yeast *Saccharomyces cerevisiae* and baker's yeast

2. Effect of treatments on the quality of banana wines

3. Quality evaluation of wines during storage

REVIEW Of LITERATURE

2. REVIEW OF LITERATURE

The literature pertaining to the study entitled "Process standardisation for banana wine" is presented under the following sub headings.

2.1. Banana - Production
2.2. Nutritional and health benefits of banana
2.3. Need for processing
2.4. Processed banana products
2.5. Fruit wines
2.6. Banana wines
2.7. Health benefits of wine

2.1. Banana – Production

Plantain fruits like bananas belong to the genus *Eumusa* (Purseglove, 1972). The banana fruit is not seasonal in nature like many other fruits and is available in fairly large quantity throughout the year (Premakumar and Khurdiya, 2002). Banana is most widely produced as a tropical fruit in more than 120 countries in the world with an annual production of 88 million tonnes from an area of 10 million hectares (Isaak *et al.*, 2006).

India is the largest producer of banana and plantains in the world with an annual production of 16.81 million tonnes from an area of 0.49 million hectar (Anon, 2002).

India has about 350 varieties of banana. Kerala is a state where eight varieties of banana are found namely *Nendran, Palayankodan* (*Mysore poovan*), *Poovan varieties, Padathy, Mondhan, Robusta, Kunnan and Kadhali*. Out of the eight varieties, *Nendran, Palayankodan* and *Poovan* were found to be of at most importance (Varkey, 1986). In 1985-86, the area under banana crop was 16500 hectares and in 2004-05 this has increased to 59000 hectares which accounts 257

percent increase. In the case of plantain, during the last 20 years, the area has increased by 50 percent. The productivity of plantain has increased from 4925 kg/ha in 1995-96 to 7619 kg/ha in 2004-05 (Government of Kerala, 2005). It has been reported by Das (2009) that about 940 metric tonnes of banana were exported in the year 2007.

In Karnataka, bananas are cultivated in about 52613 hectares, with a production of 1.3 million tonnes and a productivity of 24.6 tonnes/ha (Robinson, 1996). In Tamil Nadu, bananas are cultivated in about 88100 hectares and the total production is estimated at 4406000 tonnes (Anon., 2003).

Brazil is the second largest producer of banana with an annual production of 6.58 million tonnes (Narayana and Musthaffa, 2008).

2.2. Nutritional and health benefits of banana

Ketiku (1973) reported that plantains consist of water (66.4 g/100g), carbohydrate (31.2 g/100g of which 66% starch and 17% sugar), proteins (1.1 g/100g), fat (0.4 g/100g) and ash (0.9g/100g). Plantains as cooked bananas are nutritionally rich in carbohydrates (27%), moisture (70%), fat (0.3%) and protein (1.2%), with a good calorific value (90 calories/100g), vitamin B, C and β carotene and high level of Ca, K and P (Anon., 2002). Banana has a good source of calories, many other nutrients and enzymes. People of South India traditionally use banana as a balanced and supplementary diet. It is a wonderful nutritious diet for easy digestion, which prevents diarrhoea and worm trouble (Premakumar and Khurdilya, 2002). The nutritional constituents of large bananas were analyzed by Manzella (2009) and reported that large banana contains 2g of protein and 4g of fiber per 100g. It is also a good source of β carotene, thiamine, riboflavin, niacin, vitamin B_6, folic acid and is rich in potassium and other trace elements.

According to Chadha (1992) banana contains 27 per cent carbohydrates and provides energy. He also reported that the unripe fruit contains more starch and less sugar than ripe banana. Patel and Shurpalekar (1994) reported that plantain contained high amount of resistant starch. The average yield of starch isolated from unripe plantain was found to be 10 to 12 per cent (Sira, 1997).

Ketiku (1973) reported that ripe and unripe pulp of banana contained 1.3g and 1.6g of cellulose and 0.8g and 1.9g of hemicellulose respectively per 100g on dry weight basis. Studies conducted by Usha *et al.* (1984) revealed that in *Nendran* variety, unripe banana contained on an average 30.5 per cent neutral detergent fiber (NDF) on dry weight basis. The NDF content of ripe banana was approximately half of that present in the unripe fruit.

Sundharalingam and Ravindran (1993) reported that green banana flour contained 8.9 per cent neutral detergent fiber, 3.8 per cent cellulose, 3.1 per cent lignin and 1 per cent hemicellulose on dry weight basis. According to Ranzani *et al.* (1996) the flour prepared from banana peel contained about 32 per cent dietary fiber, while the total fiber content of banana flour varied from 6 to 15.5 per cent.

Varietal differences in the soluble and insoluble fiber content of plantains were reported by Tanya *et al.* (1997). Gopalan *et al.* (1999) reported a fiber content of 0.7g per 100g in *Nendran* variety of banana. While Thajudeen (2000) observed 0.18g per 100g of fiber in *Nendran* variety of banana. Josh (2001) indicated that banana contained about 1 per cent of fiber.

Fat content of banana is very low (Chadha, 1992). Sundharalingam and Ravindran (1993) reported a fat content of 1.3 per cent in banana flour. Chia and Huggins (1998) indicated that bananas contain about 0.5 per cent fat, while Gopalan *et al.* (1999) indicated a fat content of 0.2g per 100g in green plantain. Mota *et al.* (2000) observed 0.3 to 0.8 per cent of lipid in banana flour.

According to Gopalan *et al.* (1999) green plantain had a protein content of 1.4g per 100g. Thajudeen (2000) evaluated eleven varieties of bananas and reported that protein content varied between 0.5 to 1.74g per 100g. The author observed a protein content of 1.43g per 100g in *Nendran* variety of banana.

The protein content of green banana flour was found to be 3.2 per cent (Sundharalingam and Ravindran, 1993). Mota *et al.* (2000) studied the chemical composition of flour obtained from 8 different banana cultivars and reported a variation of 2.2 to 3.3 per cent in the protein content.

Bananas are good sources of several minerals such as calcium, potassium, phosphorus and magnesium (Singh and Uma, 1994). Whole banana is a

good source of potassium contributing to 396 mg/100g (Chia and Huggins, 1998). Izonfuo and Omurac (1998) indicated that potassium is the most abundant mineral present in green peel (37g/kg) and green pulp (8.4g/kg). Higher amount of potassium was found in green plantain than in ripe banana (Rao, 1999). Thajudeen (2000) reported a potassium content of 391.9 to 563.8 mg/100g in eleven banana varieties and the *Nendran* variety had a potassium content of 514.2mg/100g.

About 290 ppm of phosphorus and 80 ppm of calcium were found in banana (Chadha, 1992). According to Gopalan *et al.* (1992) green plantain had 10mg of calcium and 29mg of phosphorus per 100g. Thajudeen (2000) evaluated eleven varieties and reported a variation of 8.30 to 34.44 mg/100g in the calcium and 20.85 to 39.70 mg/100g in the phosphorus content.

Iron content of banana varied from 7.59 to 15.20 mg/kg (Elpo *et al.*, 1998). However Gopalan *et al.* (1999) reported an iron content of 6.27mg/100g in green plantain. The iron content of eleven banana varieties varied from 1.02 to 5.43 mg/100g (Thajudeen, 2000).

Sundharalingam and Ravindran (1993) observed an ash content of 3.7 per cent in green banana flour. Mota *et al.* (2000) observed that the ash content in banana flour ranged between 2.6 to 3.5 per cent.

According to Chadha (1992) banana contains β carotene, vitamin B and C. Singh and Uma (1994) reported that plantains are rich in vitamins, particularly vitamin C. Thajudeen (2000) evaluated eleven varieties of banana and reported that vitamin C content varied from 13.60 to 27.20 mg/100g in raw fruit.

Subagio *et al.* (1996) indicated that the carotenoid content of the banana peel varied in between 3-4 µg/g. Bananas contain high levels of carotenoids with β carotene up to 2598 µg/100g pulp (Uma *et al.*, 2008).

Animal studies conducted by Goel *et al.* (1986) indicated that oral administration of plantain powder is effective in reducing duodenal ulcer. According to Rao (1998), banana ash is rich in alkaline salts and therefore can check acidity in stomach, heart burn and colic. Rao (1999) reported that the therapeutic effect of banana against colic diseases, constipation and peptic ulcer is due to the presence of active principles like serotonin and nor epinephrine present in them. Nagarajan (2006)

stated that the fruit of *Palayankodan* is used as dietary food against intestinal disorders because of its soft texture and smoothness. It neutralizes over acidity, reduces irritation and it can be eaten without distress in chronic ulcer cases.

Mortan (1992) stated that traditionally banana is used as a balanced and supplementary diet for babies of four to ten months old. The fully matured *Nendran* fruit is powdered and is thickened by boiling with milk and sugar. In a clinical trial conducted by Arias *et al*. (1997) plantain flour based solution was proved to be effective for the treatment of dehydration due to acute diarrhoeal diseases and can be considered as an alternative for oral dehydration solution (ORS). Emery *et al*. (1997) reported that banana flakes are safe and cost effective to treat diarrhoea in critically tube fed patients. Banana flour made into gruel and diluted with milk is a good food for patients suffering from gastritis. Moreover, ripe banana fruits taken with tamarind and salt help to control dysentery (Sathyaneshan, 2006).

According to Gopalan and Ram (1990) and Rai (2000) ripe plantains have mild laxative property and hence are very useful in the diet of children, particularly as a remedy for constipation.

Bananas inhibit the angiotensin convertising enzyme which constricts blood vessel causing high blood pressure (Rao, 1999). Diller (2000) indicated that two bananas daily keep the blood pressure at bay. Rangarajan (2000) observed a 10 per cent fall in blood pressure in patients suffering from hypertension when they consumed two bananas daily for a week. The medicinal value of banana were enumerated by Jessen (2007). According to the author, the high potassium and low sodium content may prevent high blood pressure and its complications. High potassium may also prevent renal calcium loss and thereby preventing bone break down. According to Girard (2009) bananas are high in potassium and low in sodium and hence prevent high blood pressure.

Banana flour is widely used in the treatment of diabetes mellitus (Pari and Umamaheswary, 2000). The authors indicated that oral administration of the flour decreased the blood glucose, glycosylated haemoglobin and free radical formation in the tissues. The low glycaemic index of unripe banana is of particular benefit to people with diabetes (Jessen, 2007).

Panic and Thinh (2001) stated that banana fruit have a cooling effect, and can lower both the physical and emotional temperament of expecting mothers. Perera (2002) revealed that banana contains tryptophan, an amino acid that can be converted to serotonin, leading to improved mood.

Das (2009) reported that *Sooryakadali* is recommended to pregnant women as it would increase the volume of breast milk twice the normal. Snacking on bananas between meals helps to keep blood sugar level up and avoid morning sickness in pregnant women (Laxmi, 2009).

According to Janaki and Lakshmi (2008), bananas are high in B vitamins that have been shown to improve nerve function. Akrani (2008) stated that banana contain high level of natural sugar, in both their fresh and fried form, which they release quickly into the blood stream. The unique combination of vitamins and sugars within bananas release energy into the body over a long time, improving stamina and the power of endurance and concentration.

According to Rai (2000), banana has red blood cell generating potency as it stimulates the production of haemoglobin. The author also reported that banana increases alkalinity of the blood and thus corrects acidosis. Bananas are high in iron, which helps the body' haemoglobin functions and prevent anaemia (Anon. 2009).

High fructooligosaccharide content of banana may work as a prebiotic, nourishing the intestinal flora to produce beneficial vitamins and enzymes (Anon. 2009).

2.3. Need for processing

Bananas are highly perishable and must reach distant markets within a short time after harvest (Pursgelove, 1992). Waskar and Roy (1993) had reported that the large quantity of unmarketable fruits available in all banana growing region in India go as waste due to improper post harvest handling and lack of processing technology for value addition.

Suneja (2004) revealed that, due to mishandling, 25-40 per cent of banana has been wasted and only 2 per cent is processed into value added products, the remaining being used in the raw form. This leads to price imbalance and large

price variations, which dishearten the farmers. In order to sustain production and growth potential, it is essential to produce value added products based on banana, so that farmers get an assured price for their produce all the time. According to Mithra (2006), India is one of the largest producers of banana. However, this high production will have significance only when it reach consumers in good condition. Faulty handling practices coupled with underdeveloped and exploitive marketing systems result in 25-30 per cent post harvest losses and value deterioration, leaving little quantity surpluses for export and processing.

Brathwaite and Badrie (2001) indicated that bananas should be processed in order to prevent the loss of tremendous quantities of these fruits, either through over production or in grading to meet quality standards for export market. Farmers in the Caribbean are often faced with the problem of excess production of bananas resulting in spoilage, wastage of fruit and lower returns (Bramwell and Badrie, 2002). Fresh green plantains are grown in the southern parts of tropical region of India, and have short shelf life of five to six days at ambient storage conditions (Isaak *et al*., 2006).

Kaur (2006) indicated that bananas are available in plenty in the tropical countries but due to poor transportation and storage facilities the fruits get wasted. Therefore the author suggests that processing and product development using bananas into various products are necessary.

2.4. Processed banana products

Ripe and unripe banana can be readily processed into pulp, liquid fruit, canned slices, deep fried chips, toffees, figs, fruit bar and brandy (Chadha, 1992). *Nendran* is used as breakfast food after steaming. It is also used for the preparations such as halwa, sweets and chips (Aravindakshan and Pushkaran, 1996). Fresh fruit is eaten as dessert while unripe fruits and fruits from cooking types of banana (plantains) are used as vegetable. It can be boiled, steamed, roasted, baked, fried or even fermented to produce beer or vinegar (Isaak *et al*., 2006). According to Koeppel (2008), a minor proportion of the total world banana production is processed into canned slices, dried slices or flakes, frozen juice, and fermented products. Puree is canned or frozen and used in baby foods, baked items and beverages.

Banana chips is one of the most popular processed product of banana, which can be easily produced (Hameed, 1981). According to Uma *et al*. (1999) banana chips made from *Nendran* was found to be the best. In the Caribbean, plantains are boiled or fried and eaten as chips (Simon and Badrie, 2002). Studies conducted by Lakshmi (2003) revealed that banana chips prepared from *Attunendran* and *Changalikodan* (Nendran varieties) were the best in terms of acceptability and nutrition.

Thajudeen *et al*. (1996) suggested that banana flour prepared from raw fruit is a highly nutritive baby food. *Kunnan* and *Nendran* varieties of banana are suitable to prepare weaning foods (Singh and Uma, 1997). Usually banana flour is prepared from unripe fruit and banana powder from ripe fruits (Rao, 1998).

Prasad (1998) conducted a study to develop a nutritious, low cost and acceptable weaning food with banana flour. Weaning food containing banana flour, horse gram, sesame and skim milk powder in the ratio 3:2:3:2 gave the most satisfactory product with respect to acceptability. Giraldo (2000) developed a weaning food with banana flour enriched with defatted soybean flour, vitamins and minerals.

According to Muyonga (2001) banana flour produced by predehydration and steaming gives pastes of low paste bulk density, which is desirable for weaning and supplementary foods. A highly nutritious weaning food was prepared using banana pumpkin slurry, cow pea flour, rice and skim milk powder (Jirapa *et al*., 2001). According to Benjamin (2007), *Kunnan* and *Nendran* bananas are ideally suited for baby foods.

Banana figs, which are sun dried slices of fruit, are commonly prepared in many countries (Robinson, 1996). Banana figs or fingers according to Banks (2000) are usually whole peeled fruit carefully dried so as to retain their shape although sometimes the fruit is sliced or halved to facilitate drying.

Banana puree is most widely used as raw material for other value added products from banana. It contributes to the flavour of a wide variety of food products and its functional properties are also of value (Jonas, 1994). Banana puree is obtained by pulping peeled ripe bananas and then preserving the pulp by acidification, aseptic method or by quick freezing (Dauthy, 1995). According to Bose *et al*. (1999) banana

puree is one of the most important processed products prepared from the pulp of ripe fruit. The puree is canned and used as an ingredient in dairy dessert, baking items and beverages.

According to Dauthy (1995) best quality canned slices are obtained from fruit at an early stage of ripeness. Thomson (1998) reported that canned banana slices are used in tropical fruit salad.

In East Africa, ripe banana is used to make a beer with low alcohol content (Acland, 1971). Adams (1978) described a procedure for making vinegar from ripe banana. Sharrock (1996) mentioned that a banana beer low in alcohol content and short shelf life was made from the juice of ripe bananas in several part of Africa. According to Singh and Uma (1997), Cavendish bananas are found to be the best for wine while 'pisang Awak' is best for beer production. Someya *et al*. (2002) reported that banana with acid taste are used to make beer and wine.

Banana jam is made by boiling equal quantities of fruit and sugar together with water, lemon juice or citric acid (Dauthy, 1995). According to Bose *et al*. (1999) ripe banana is used as an important component of mixed fruit jam.

Products like jellies, jams, halwa, figs and toffee were successfully prepared from banana varieties like *Morris, Rajthali* and *Nattupazham* (Premalatha and Manimagalai, 1996). The authors also found that fruit toffee prepared in combination with pine apple, pumpkin, beet root and potato with banana was highly acceptable.

Narayana *et al*. (2007) reported that a tasty fruit bar can be prepared by mixing 20 per cent sugar, 0.5 per cent pectin and 350ppm potassium metabisulphite with the smoothly blended pulp of *Karpooravalli* banana.

Panchamritham and *Rasayanam* are prepared from ripe banana fruit (Sathyaneshan, 2006). Over ripe banana and acid whey are combined to form a nutritious beverage called whey banana shake and whey banana (Shekilango *et al.*, 1997).

Sharon (2010) has suggested that probiotically fermented product using banana flour along with other ingredients like defatted soya flour and green gram flour is a highly acceptable and nutritious health drink.

2.5. Fruit wines

Fermented fruit beverages have been known to mankind from time immemorial. The Vedic 'Soma Rasa' also is a kind of fermented juice. Wines made from fruits are named after the particular fruit employed (Lal *et al.*, 1998). Wine is the oldest of the alcoholic beverages made by the fermentation of grape juice. Wines may be either 'dry' or 'sweet' depending upon the extent to which the fermentation has taken place. Most of the natural wines contain 8-10 per cent alcohol. Fortified wines contain about 20 per cent alcohol. Wines containing less than 14 per cent alcohol are table wines while those which contain more are dessert wines (Manay and Shadaksharaswamy, 2000). Sudheer and Indira (2007) indicated that natural wine contains 6 to 8 per cent alcohol. Wines with 7 to 9 per cent alcohol are branded as light wine, those with 9 to 16 per cent as medium and wines with 16 to 20 per cent alcohol are considered as strong wine. The authors also indicated that sweet wines contain above 4 per cent sugar, semi sweet wines had 2.5 to 4 per cent and dry wines less than 2.5 per cent sugar.

Fortified grape wines are made by adding spirit to wine, either during or after fermentation, with the result that the alcohol content of the wine is raised to around 20 per cent (Rose, 1961). Sulphur dioxide, more than 250mg per litre maintained the colour of fruit wines during storage (Ogino *et al.*, 1982).

Method of preparing fruit wine of improved quality was suggested by Skrypnik (1983). He said that the juice of low acid apples or pears should be blended with high acid black currant or gooseberry pulp. The juice was then extracted and fermented.

Vinegar is the product made traditionally by alcoholic fermentation followed by acetic fermentation with acetobactor. It can be made from any substrate that can undergo alcoholic fermentation of fruit juices and hydrolysed starchy materials. Wines and fermented apple juice are common substrates. Cider vinegar malt vinegar, fruit vinegar and rice vinegar are some varieties (Allgeier, 1985).

Onkarayya (1985) developed mango vermouth by mixing herb mixtures of 14 herbs in different proportions (forming four formulae) to improve the aroma and taste of mildly flavoured mango wine prepared using dilute pulp. Vermouth is an alcoholic beverage prepared from fruit wines by adding extracts of spices and herbs (Ethiraj and Suresh, 1990).

Lubisi is an orange alcoholic beverage made from bananas of Jamaican variety. It is sweet and slightly hazy with a shelf life of several days under correct storage condition (Lange, 1985).

A methodology for making wine from *jambal* was standardised by Shukla *et al*. (1991). They also screened three cultivars namely, *pharenda, jamun* and *kathajamun* for evaluating their suitability in wine making and concluded that *jamun* gave the best wine. Dirar (1992) reported that date wine known as *Dakhai* was produced using 2 to 4 volumes of boiling water for every one volume of dates in earthen ware pot. It was then cooled and sealed for 7 to 10 days. The author also reported different variations of date wine known as *El madfuna* produced by burying the pot filled with wine mixture, *Benti merse* produced from a mixture of sorghum and dates and *Nebit* produced from date syrup.

Fruit wines refer to the fermented juice of fruits other than grapes (Pilgrim, 1994). Kotecha *et al*. (1995) standardised wine with custard apple and reported that custard apple wine was comparable to that of grape wine in terms of body and taste. Jack fruit wine is an alcoholic beverage produced from pulp of jack fruit. Fermented wine inoculum is used for fermentation. Fermentation takes place at 18 to 30ºC for seven days and pH was found to be 3.5 to 3.8 (Steinkrans, 1996). *Basi*, a sugar cane wine is prepared by fermenting, freshly extracted sugar cane juice using a dried powdered starter (Steinkrans, 1996). Cashew wine is a light yellow alcoholic drink prepared from the cashew fruit. It contains an alcohol content of between 6 and 12 per cent (Azam-Ali, 1998).

According to Bhajipale *et al*. (1998) the alcohol content of most fruit wines is about 12 per cent. Karonda fruits of different ripening stages were chemically analysed and used for wine making by Bhajipale *et al*. (1998). Overripe fruits produced tasty, cherry red coloured wine with 8.26 per cent alcohol and 438 ml/kg wine yield.

Lal *et al*. (1998) prepared two types of wines from grapes namely dry and sweet wine and reported that the alcohol content of these two kinds of wines ranged from 7 to 20 per cent.

Singh *et al*. (1998) conducted studies on the suitability of kinnow fruits for wine production and used *Saccharomyces cerevisiae* MTCC 178 for production of wine from kinnow juice.

Gautam and Chundawat (1998) standardised the technology of making wine from sapota. The wine prepared from clarified juice was preferred to that made from non-clarified juice or to that from pulp.

Cider is an alcoholic beverage made from the fermented juice of apples. It varies in alcohol content from less than 3 per cent to 8.5 per cent (Mangas, 1999).

Feni is an alcoholic beverage made from cashew apple juice (Girdhari *et al*., 1998). The wine prepared from clarified juice was preferred to that made from non-clarified juice. The results of the study conducted by Carvalho (2001) revealed that among the three strains of wine yeast *viz*. MTCC 172, MTCC 174 and MTCC 180, the latter was more effective in wine production from cashew apple juice.

According to Robinson (2006), sparkling wines such as champagne contain carbon dioxide which is produced naturally from fermentation or force-injected later. To have this effect, the wine is fermented twice, once in an open container to allow the carbon dioxide to escape into the air, and a second time in a sealed container, where the gas is caught and remains in the wine. Pulque is made by fermentation of the juice of agave in Mexico. It is consumed as a nutritional supplement (Medindia, 2007).

2.6. Banana wine

Kordylas (1990) reported that the peel and pulp of ripe bananas contain appreciable amounts of fermentable sugars that can be used for alcoholic fermentation. Fermentation is a process in which yeast convert the sugars in the fruit juice to alcohol, carbon dioxide and small amounts of various byproducts (Cariri, 1992). Simmonds (1996) revealed that banana wines that are not fortified with sugar are weak and have a short shelf life.

According to Rombouts and Pilnik (1978), pectic and celluloytic enzymes are commonly used in the industry to aid in juice clarification and increased yield. Also, the addition of the fining agent, bentonite aided in the settling of suspended banana particles and dried yeast cells, resulting in the improvement of clarity.

Koffi *et. al.* (1991) showed that pectic enzymes can reduce viscosity and increase filterability of banana puree. Vamos-Vigyazo (1995) reported that addition of potassium metabisulphite can control enzymatic and non enzymatic browning in fruit pulps. Bramwell (1998) reported 0.30 per cent pectin as calcium pectate in banana pulp, which can result in colloidal suspension in banana wines, and this make filtration and juice extraction more difficult.

Cheirsilp and Umsakul (2000) treated banana must with pectinase and α-amylase to hydrolyse pectin and starch to produce banana wine. Enzyme treated banana must was diluted with four volumes of water and then fermented by yeast to produce wine. The authors reported that reducing sugars were higher than that of nonenzyme-treated banana wine during fermentation. The clarity of the enzyme treated banana wine was also fourfold higher than that of the nonenzyme-treated banana wine. The concentrations of total soluble solids, total soluble sugars and alcohol in the enzyme-treated banana wine and nonenzyme-treated banana wine have no significant differences.

Onwuka and Awam (2001) found that the fermentable sugar level of banana wine was 18.81 to 23.57 per cent. The wine had an alcohol content of 9.96 to 11.25 per cent, TSS of level 8.0 to 8.15°Brix and titrable acidity 1.00 to 1.108 per cent. Sensory evaluation indicated significant differences in taste, colour and general acceptability among the wines.

Studies conducted by Brathwaite and Badrie (2001) revealed that inclusion of pectolase improved the clarity and addition of sodium metabisulphite produced a more intense yellow wine with banana. There were no differences for most of the quality attributes in banana wines fermented longer than three weeks. Jackson and Badrie (2002) reported that addition of pectolase enzyme had no effects on percentage wine yield, degree brix, percentage alcohol, sulphur dioxide, pH or titrable acidity, except for colour, volatile acidity and tannin content in banana wine.

Akubor *et al.* (2003), extracted banana juice and adjusted the sugar to 18ºBrix and 1.4 mg/100ml vitamin C and conducted sensory evaluation. The results showed that there were no significant differences in flavour, taste, clarity and overall acceptability between banana wine and a reference wine.

2.7. Health benefits of wine

There is no doubt that wine is a healthful beverage. It has been consumed through the ages as food and as a food adjunct. It may indeed be considered as the world's oldest medicine. Modern scientists believe that wine is one of the most complex beverages containing many substances that are important to health. As a dietary liquid, it is second only to that of milk (Blevins and Morris, 1997).

Alcohol present in wine enhances high density lipoproteins by facilitating excretion of cholesterol *via* liver, reduces the concentration of the atherogenic apo protein A-1 and also reduces stress (Finkel, 1996). Watkins (1997) reported that wine is a rich source of flavanoids and other polyphenolic antioxidants, which protect the body from cardiovascular diseases.

According to Sato (1998), moderate consumption of wine reduces stress and decreases LDL levels. He also suggested that an alcohol intake of 10 to 30 g/day can reduce the risk of cardiovascular disease. Red wine contains many phenolics, which elevate plasma antioxidant activity and can provide protection against diseases such as dementia, alzheimer's disease and stomach cancer.

Romero *et al.* (2001) found that the individuals who consume wine more than three times a week showed higher selenium concentration than individuals with lower consumption. The lower serum selenium concentration increases the risk of cardiovascular disease and cancer.

Phenolic substances present in wine can prolong the time for platelet aggregation and blood clot formation and may stimulate vasorelaxation of blood vessels (Dubick and Omaye, 2001).

According to Dixon *et al.* (2002) mild to moderate consumption, especially red wine consumption, lower the fasting homocystein concentration in obese. This may reduce cardiovascular risk.

Peregrin (2005) reported that red wine reduced the risk of coronary heart disease, lung cancer and prostate cancer. Consumption of red wine was found to reduce the risk of CVD mortality rates (Pal, 2005). The author found that red wine polyphenolics attenuated the synthesis and secretion of proatherogenic chylomicrons from intestinal cells and thereby reduced the risk of CVD.

Bantle *et al*. (2008) observed that moderate consumption of alcohol in the form of wine is associated with reduced CVD rates in non diabetes population by raising the plasma HDL level.

Phenolic compound tannin, present in wine, exerts broad cancer chemo protective activity (Nepka *et al*., 1999). Sesso *et al*. (2001) reported that moderate consumption of wine reduced the risk of prostate cancer. A naturally occurring phenolic compound in wine, resveratrol, act as an antimutagenic/ anticarcinogenic agent by preventing oxidative DNA damage (Sgambato *et al*., 2001).

Resveratrol present in wine inhibits the metabolic activation of carcinogens, has antioxidant and anti-inflammatory properties, decreases cell proliferation and induces apoptosis (Bianchini and Vainio, 2003).

Polyphenolic compound delphinidin, present in wine, may preserve endothelium integrity, the alteration of which lead to pathologies including cardiovascular diseases, such as arthrosclerosis, and is often associated with cancers (Martin *et al*., 2003).

Resveratrol present in wine act as an antioxidant, which promote nitric oxide production, inhibit platelet aggregation and increase high density lipoprotein cholesterol and thereby serve as a cardio protective agent and also function as a cancer chemo preventive agent (Wolter *et al*., 2004).

Renand *et al*. (2004) reported that a moderate intake of wine is associated with a lower risk of mortality from all causes in persons with hypertension. Ravina *et al*. (2004) reported that each glass of wine a day reduced the risk of lung cancer by 13 per cent compared to non-drinkers.

Salicyclic acid (SA) a phenolic compound in wine is related to health due to fibrinolytic activity in whole blood. SA is important in prevention of

inflammation and provides serenogenic effects (relaxant). SA (salicyclic acid) protects against the vehicular emission, smog and tobacco smoke containing oxides of nitrogen – thus preventing lung cancer, respiratory tract infection and other pathological states (Sharada, 2004).

Experimental and epidemiological studies conducted by Nifli, *et al*. (2005) indicated that polyphenols in wine and other polyphenol rich dietary foods have antioxidant property. The authors observed that the polyphenols showed antimitotic activities which interfered with human breast cancer initiation, progression or mortality.

People who smoke and drink at least one glass of wine each day are 60 percent less likely to develop lung cancer than those who smoke and do not drink red wine (John, 2008). Moderate consumption of red wine may decrease the risk of lung cancer in men, particularly among smokers (Chao, 2008).

Bujanda (2000) reported that alcoholic beverages, especially wine, have important antibacterial effects upon *Helicobactor pylori* and other enteropathogenic bacteria. Low concentration of ethanol (4-8%) present in wine inhibits the growth of mold, yeast and many bacteria (Steinkrans, 2004). According to Daglia *et al*. (2007) both red and white wines are effective anti-bacterial agents against strains of *Streptococcus*.

Both red and white wines enhance iron absorption from foods due to the simple phenolics in wine (Hymavathy, 2004).

Antioxidants present in wine reduce peroxidation of polyunsaturated fatty acids (PUFA) and low density lipoproteins and also reduce chronic inflammation tendencies by decreasing peroxides (Evans and Miller, 1995). Wine antioxidants help to prevent, though indirectly, diabetes (including that caused by iron over load) and associated visual loss (Joshi and Pandey, 2004).

Epidemiological study conducted by Leighton *et al*. (2006) observed protective effect of red wine against metabolic syndrome due to the presence of endothelial nitric oxide synthase (eNOS).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present investigation on 'Process standardisation for banana wine' was undertaken in the Department of Home Science, College of Horticulture, Vellanikkara.

The research programme was undertaken under the following three experiments:

3. 1. Standardisation of banana wine with pure strains of wine yeast and with baker's yeast

3. 2. Effect of treatments on the quality of banana wines.

3. 3. Quality evaluation of wines during storage.

Collection of banana

Fully ripe bananas (*Palayankodan*) were collected from the local market. A visible sign of change in skin colour was considered in judging the ripeness of bananas and also change in the ridges of the skin from angular to round (Ramana and Jayaraman, 1994).

3. 1. Experiment 1. Standardisation of banana wine with pure strains of wine yeast and with baker's yeast.

The experiment was aimed to standardise techniques for the preparation of banana wine and to evaluate the suitability of three different strains of wine yeast, *Saccharomyces cerevisiae*, viz., MTCC 172, MTCC 174 and MTCC 180. These strains were obtained from the Institute of Microbial Technology (IMTECH) Chandigarh, Punjab. IMTECH is marketing these strains as ideal strains for making wine. Wine was also standardised with baker's yeast. Baker's yeast was purchased from the local market.

3. 1. 1. Preparation of starter culture with pure strains

Freeze dried cultures in vacuum sealed glass ampules 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. Later the petri plates were incubated in a B.O.D incubator at 37˚ C for a period of two days.

3. 1.1. 1. Subculturing the yeast

To prevent the contamination of the yeast colonies by other organisms, subculturing was done at bimonthly intervals. Here, a single colony of yeast was taken in a sterile loop and streaked on petri plates with fresh media. Only single colonies of yeast were used for inoculating banana wine.

3. 1. 1. 2. Standardisation of inoculum concentration

For the production of wine of generally accepted taste and quality, the fruit pulp has to be inoculated with a population of yeast of 10^6 or 10^7 colony forming units (cfu) per ml of juice (Battock and Azam-Ali, 1998). The period taken by the yeast cells to attain the desired population, from the time of inoculation into liquid growth media was noted. Single colonies were inoculated in 10 ml of the medium and incubated in B.O.D. incubator at 37˚ C. Population was enumerated at 24 hour interval by serial dilution plating on the specified medium contained in petri plates. The plates were incubated for 48 hours, number of colonies were counted and expressed as cfu per ml.

3. 1. 2. Preparation of starter culture with baker's yeast

Starter culture was prepared using commercial baker's yeast, *Saccharomyces cerevisiae* as standardised by Carvalho (2001). Sugar was dissolved in luke warm

water at the rate of 20 g per 100 ml of water. Baker's yeast was then added at 5 g per 50 ml of the sugar solution. The culture was kept as such for 30 to 60 minutes for vigorous frothing. Population was enumerated by serial dilution plating on the specified medium contained in petri plates. The plates were incubated for 48 hours, number of colonies were counted and expressed as cfu per ml.

3. 1. 3. Development of wines

Wines were developed with one kg of peeled pureed bananas (Plate No. 1 and 2) and one liter water with added sugar to obtain 20˚ Brix. The starter culture of three different strains of wine yeasts and baker's yeast were used for fermentation and for each, two concentrations of the cultures (10^6 and 10^7 cfu per ml) were used for inoculating the mixture. The culture was inoculated with 0.23 ml (10^6) and 2.3 ml (10^7) of MTCC 172, 0.25 ml (10^6) and 2.5 ml (10^7) of MTCC 174, 0.24 ml (10^6) and 2.4 ml (10^7) of MTCC 180 and 0.2 ml (10^6) and 2.0 ml (10^7) of baker's yeast.

The treatments used are as detailed below.

T_1 Banana pulp (1 kg) + Water (1000 ml) + Sugar to raise TSS to 20˚ Brix + S_1 (10^6) (0.23 ml)

T_2 Banana pulp (1 kg) + Water (1000 ml) + Sugar to raise TSS to 20˚ Brix + S_1 (10^7) (2.3 ml)

T_3 Banana pulp (1 kg) + Water (1000 ml) + Sugar to raise TSS to 20˚ Brix+ S_2 (10^6) (0.25 ml)

T_4 Banana pulp (1 kg) + Water (1000 ml) + Sugar to raise TSS to 20˚ Brix + S_2 (10^7) (2.5 ml)

T_5 Banana pulp (1 kg) + Water (1000 ml) + Sugar to raise TSS to 20˚ Brix + S_3 (10^6) (0.24 ml)

T_6 Banana pulp (1 kg) + Water (1000 ml) + Sugar to raise TSS to 20˚ Brix + S_3 (10^7) (2.4 ml)

Plate 1. Banana (*Palayankodan*)

Plate 2. Banana pulp

T_7 Banana pulp (1 kg) + Water (1000 ml) + Sugar to raise TSS to 20˚ Brix + BY (10^6) (0.2 ml)

T_8 Banana pulp (1 kg) + Water (1000 ml) + Sugar to raise TSS to 20˚ Brix + BY (10^7) (2.0 ml)

S_1 = MTCC 172 S_2 = MTCC 174 S_3 = MTCC 180

BY = Baker's yeast

All fermentations were carried out in ambient temperature in china clay jars by appropriate sealing for four weeks.

3. 1. 4. Physico chemical qualities of banana wines with pure strains and baker's yeast

3. 1. 4. 1. Wine yield

At the end of fermentation, the wine was decanted leaving the dead yeast cells and other residue at the bottom of the fermenting jar. The wine yield was expressed as a percentage of its weight.

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

3. 1. 4. 2. Clarity

Wine clarity was measured by the procedure suggested by Brathwaite and Badrie (2001). It was expressed as percent light transmittance and was read at 470 nm in a spectrophotometer using distilled water as the standard with 100 per cent transmittance.

3. 1. 4. 3. Alcohol content

Alcohol content was estimated by the method suggested by Saini *et al*. (2001). Prepared standard ethanol solutions in water ranging from 1-5 percent. Took one ml of wine sample from each and made up the volume to 50 ml in volumetric

flasks. Took 10 ml of the diluted sample in a distillation flask, added 30 ml of distilled water and distilled. Collected about 20 ml of the distillate in a volumetric flask containing 25 ml of chromic acid. Incubated this at 60^0 C for 20 minutes. Cooled to room temperature and made up the volume to 50 ml. OD was read in a spectrophotometer at 600 nm. Prepared a standard curve by plotting OD against the concentration of alcohol. Determined the OD of the wine sample by the same procedure and alcohol content was found out from the standard curve.

3. 1. 4. 4. pH of the wine

The pH of the wine at the end of fermentation was recorded using standard pH meter.

3. 1. 4. 5. Titrable acidity

Titrable acidity was estimated as per A.O.A.C. (1980). Twenty five ml of the wine sample was made up to a known volume with distilled water. An aliquot of the solution was titrated against 0.1 N sodium hydroxide solution using phenolphthalein as indicator. The acidity was expressed as percentage of malic acid.

3. 1. 4. 6. TSS of wine

The TSS content of the wine was estimated using the Erma hand refracto meter (range 0-32˚ brix).

3. 1. 5. Acceptability of fresh wines with pure strains and baker's yeast

3. 1. 5. 1. Selection of judges

A series of acceptability trials were carried out using simple triangle test at the laboratory level and selected a panel of 10 judges between the age group of 18-35 years as suggested by Jellinek (1985).

3. 1. 5. 2. Preparation of score card

Score cards were prepared for the sensory evaluation of the wines and this is given in Appendix I.

3. 1. 5. 3. Sensory evaluation

Sensory evaluation of the wines were carried out using score cards based on a nine point hedonic scale by a panel of 10 selected judges. The quality attributes namely colour and appearance, flavour, astringency (desirable level), sugar acid blend, taste, alcohol strength (acceptable level) and over all acceptability was evaluated.

3. 1. 5. 4. Selection of yeast strains with the most acceptable wines

From the above experiment, one treatment with pure strain and one treatment with baker's yeast were selected based on the overall acceptability of the wines.

3. 2. Experiment 2. Effect of treatments on the quality of banana wines

The pure strain and baker's yeast in standardised concentration from the previous experiment were used in this study, for wine development. Pectic and celluloytic enzymes are commonly used in the industry to aid in juice clarification and increased yield. Koffi *et. al*. (1991) showed that pectic enzymes can reduce viscosity and increase filterability of banana puree. A polyphenoloxidase enzyme has been isolated from banana pulp, which can catalyse the oxidation of a variety of diphenolic substances. Dopamine was reported to be the most reactive substrate for browning in banana pulp (Palmer, 1971). The addition of potassium metabisulphite can control both enzymatic and non enzymatic browning in wines (Lambrecht, 1994).

Hence, in this experiment banana pulp was treated with commercial food grade pectinase and potassium metabisulphite (KMS). Peeled bananas were also pressure cooked (one kg with 250 ml water) for five minutes, as one treatment.

The treatments are as detailed below.

T_1 Banana pulp (1 kg) + Water (1000 ml) + Sugar to raise TSS to 20˚ Brix + PS (control)

T_2 Banana pulp (1 kg) + Water (1000 ml) + Sugar to raise TSS to 20˚ Brix + PS + enzyme (0.3%)

T_3 Banana pulp (1 kg) + Water (1000 ml) + Sugar to raise TSS to 20˚ Brix + PS + KMS (150 ppm)

T_4 Banana pulp (1 kg) + Water (1000 ml) + Sugar to raise TSS to 20˚ Brix + PS + enzyme (0.3%) + KMS (150 ppm)

T_5 PCS (1 kg peeled banana) + Water (1000 ml) + Sugar to raise TSS to 20˚Brix + PS

T_6 PCS (1 kg peeled banana) + Water (1000 ml) + Sugar to raise TSS to 20˚Brix + PS + enzyme (0.3%)

T_7 PCS (1 kg peeled banana) + Water (1000 ml) + Sugar to raise TSS to 20˚ Brix + PS + KMS (150 ppm)

T_8 PCS (1 kg peeled banana) + Water (1000 ml) + Sugar to raise TSS to 20˚ Brix + PS + enzyme (0.3%) + KMS (150 ppm)

(Same treatments were also done with baker's yeast, 10^6 concentration. Total 16 treatments)
PS = Pure strain (MTCC 172, 10^6) PCS = Pressure cooked substrate
KMS = Potassium metabisulphite

In treatments with potassium metabisulphite, the inoculum was added after 24 hours treatment with potassium metabisulphite. Fermentations were carried out in ambient temperature in china clay jars by appropriate sealing for four weeks.

3. 2. 1. Physico chemical attributes of banana wines with different treatments

The physico chemical parameters of wines such as wine yield, clarity, alcohol content, pH, titrable acidity and TSS were assessed as described in 3. 1. 4. 1, 3. 1. 4. 2, 3. 1. 4. 3, 3. 1. 4. 4, 3. 1. 4. 5 and 3. 1. 4. 6. respectively.

3. 2. 2. Acceptability of wines with different treatments

The sensory evaluation of the wines were conducted as described in 3. 1. 5. 3. From these treatments, four wines (two from pure strain and two from baker's yeast) with maximum quality attributes (alcohol content that of a medium wine 8 – 12 % and acceptability as judged by the panel members with highest overall acceptability score) were selected for shelf life studies.

3. 3. Experiment 3. Quality evaluation of wines during storage

The selected wines were pasteurised and bottled in amber coloured bottles with cork caps and stored at ambient temperature for a period of three months. Quality evaluation of the wines were carried out initially before pasteurisation and finally after storage.

3. 3. 1. Physico chemical attributes of banana wines during storage

3. 3. 1. 1. Clarity

Clarity of wines were determined as described in 3. 1. 4. 2.

3. 3. 1. 2. Alcohol content

Alcohol content was determined as described in 3. 1. 4. 3.

3. 3. 1. 3. pH

pH was determined as in 3. 1. 4. 4.

3. 3. 1. 4. Titrable acidity

Titrable acidity was determined as in 3. 1. 4. 5.

3. 3. 1. 5. TSS

TSS was determined as in 3. 1. 4. 6.

3. 3. 1. 6. Reducing sugar

Reducing sugar was estimated by the method given by Lane and Eynon (Ranganna, 1986). To 25 ml of the wine sample, 250 ml of distilled water was added and then clarified with neutral lead acetate. The excess lead acetate was removed by

adding potassium oxalate. The volume was then made up to 250 ml. An aliquot of this solution was titrated against a mixture of Fehling's solution A and B using methylene blue indicator. The reducing sugar was expressed as percentage.

3. 3. 1. 7. Total sugars

The total sugar content was determined using the method given by Lane and Eynon (Ranganna, 1986). The clarified solution (25 ml) as in the case with reducing sugars was boiled gently after adding citric acid and water. It was later neutralized with NaOH and the volume was made up to 250 ml. An aliquot of this solution was titrated against a mixture of Fehling's solution A and B. The total sugar content was expressed as percentage.

3. 3. 1. 8. Pectin

Pectin content was determined by the method given by Sadasivam and Manickam (1992). Fifty ml of the sample was taken in a 1 liter beaker and 300 ml of 0.01 N HCl was added and was boiled for 30 minutes and filtered. Residue was washed with hot water and the filtrate was collected. Hundred ml 0.05 N HCl was added into the residue and was boiled for 20 minutes and filtered. To the filtrate added 100 ml of 0.3 N HCl, boiled for 10 minutes, filtered, washed and collected the filtrate. The filtrate was pooled and made up to 500 ml. Hundred ml to 200 ml aliquot was taken in 1 litre beaker and 250 ml of water was added. Then neutralised the acid with I N NaOH using phenolphthalein indicator. Added excess of 10 ml of 1 N Na OH with stirring and allowed it to stand overnight. Fifty ml of I N acetic acid was added into it. After 5 minutes, 25 ml of I N $CaCl_2$ solution was added with stirring and allowed it to stand for one hour. The mixture was boiled for 1-2 minutes and then filtered through a pre weighed filter paper. The precipitate was washed with boiling water to make the filtrate free from chloride. The filter paper with calcium pectate was transferred and dried overnight at 100^0C in a weighing dish, cooled in a desicator and weighed. After weighing, the amount of pectin was calculated and expressed as percentage of calcium pectate.

3. 3. 1. 9. Tannin

The tannin content was determined tannic acid by colorimetric method using Folin-Denis reagent (Sadasivam and Manickam, 1992). One ml of sample was

pipetted out to a volumetric flask having 75 ml water, added 5 ml Folin-Denis reagent and 10 ml of sodium carbonate solution and diluted to 100 ml with water and shook well. After 30 minutes the absorbance was read at 700 nm. The tannin content was calculated from the standard graph prepared using serial dilution of standard tannic acid.

3. 3. 2. Acceptability of wines during storage

Sensory evaluation of the wines after storage was conducted as described in 3. 1. 5. 3.

3. 3. 3. Enumeration of total microflora in wines

Enumeration of total microflora in wines was done initially before pasteurisation and finally after storage by serial dilution and plate count method as described by Agarwal and Hasija (1986). One ml of the sample was transferred to a test tube containing 9 ml water blank to get 10^{-2} dilution. Similarly, 10^{-3}, 10^{-4}, 10^{-5}, and 10^{-6} dilutions were also prepared serially.

Enumeration of total micro flora was carried out using Nutrient Agar medium for bacteria, Potato Dextrose Agar for fungi and Saboraud Dextrose Agar for yeast.

3. 3. 4. Cost of production of the most acceptable wine

Cost analysis of the product was done to assess the extent of expense incurred to prepare the product.

The cost was worked out based on the amount incurred on the raw materials used and labour cost for the preparation of wine. The cost of banana wine was compared with the cost of locally available grape wine prepared and sold by individuals.

3. 3. 5. Statistical analysis

The observations recorded were tabulated and the data was analysed statistically as Completely Randomised Design (CRD). Among treatments comparisons were made by applying DMRT and each treatment with pure strain and baker's yeast was compared by applying paired 't' test. For organoleptic studies, Kendall's coefficient of concordance was used to assess the degree of agreement

among the judges. Comparison of the stored wines were analysed by paired‘t’ test and Wilcoxon Signed Rank Test.

RESULT

4. RESULT

The results pertaining to the study entitled "Process standardisation for banana wine" is presented under the following headings.

4. 1. Standardisation of banana wines with pure strains of wine yeast and with baker's yeast

4. 1. 1. Standardisation of inoculum concentration

4. 1. 2. Physico chemical qualities of banana wines prepared with pure strains and baker's yeast

4. 1. 3. Sensory evaluation of banana wines prepared with pure strains and baker's yeast

4. 1. 4. Selection of yeast strains with the most acceptable wines

4. 2. Effect of treatments on the quality of banana wines with selected yeast strains

4. 2. 1. Effect of treatments on the physico chemical attributes of banana wines

4. 2. 2. Effect of treatments on the organoleptic qualities of banana wines with selected yeast strains

4. 2. 3. Selection of good quality wines for storage studies

4. 3. Quality of banana wines during storage

4. 3. 1. Physico chemical attributes of banana wines in storage

4. 3. 2. Organoleptic qualities of wines in storage

4. 3. 3. Total microbial count of wines in storage

4. 4. Cost of production of the most acceptable wine

4. 1. Standardisation of banana wines with pure strains of wine yeast and with baker's yeast

4. 1. 1. Standardisation of inoculum concentration with pure strains and baker's yeast

As revealed in Table 1, the pure strains of MTCC 172, MTCC 174 and MTCC 180 used for inoculation, contained $1200x10^6$ cfu/ml and $120x10^7$ cfu/ml, $1100x10^6$ cfu/ml and $110x10^7$ cfu/ml, $1160x10^6$ cfu/ml and $116x10^7$ cfu/ml of broth respectively (Plate No. 3, 4 and 5). The baker's yeast used for inoculation contained $1530x10^6$ cfu/ml and $153x10^7$ cfu/ml. Hence, the inoculum quantity used for pure strains were 0.23 ml (10^6) and 2.3 ml (10^7) for MTCC 172, 0.25 ml (10^6) and 2.5 ml (10^7) for MTCC 174, 0.24 ml (10^6) and 2.4 ml (10^7) for MTCC 180 per kg of banana pulp. For baker's yeast, 0.2 ml (10^6) and 2.0 ml (10^7) were used for 1 kg of banana pulp. (Total eight treatments).

Table 1. Yeast count (cfu/ml) and inoculum (ml) used for wine standardisation

Wine yeast culture	Yeast count (cfu/ml)		Inoculum used (ml)/ kg banana pulp	
	10^6 dilution	10^7 dilution	10^6 dilution	10^7 dilution
MTCC 172	1200	120	0.23	2.3
MTCC 174	1100	110	0.25	2.5
MTCC 180	1160	116	0.24	2.4
Baker's yeast	1530	153	0.20	2.0

4. 1. 2. Physico chemical qualities of banana wines prepared with pure strains and baker's yeast

The banana wines with pure strains and baker's yeast (10^6 and 10^7 dilution) were evaluated for different attributes like wine yield, clarity, alcohol content, pH, titrable acidity and TSS. The results relating to the physico chemical parameters of banana wines are presented in Table 2.

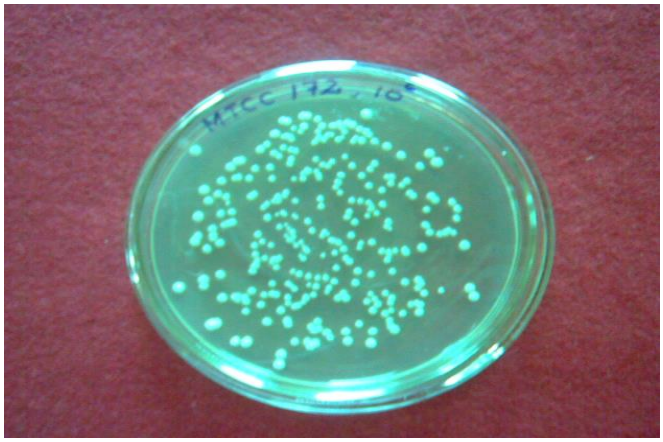


Plate 3. Population of MTCC 172 10^6 dilution

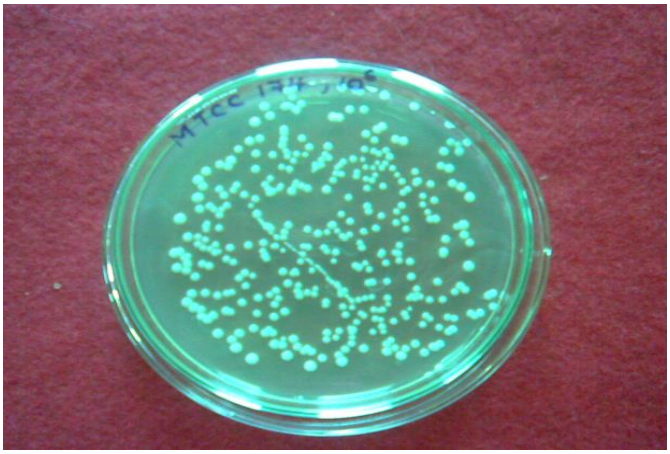


Plate 4. Population of MTCC 174 10^6 dilution

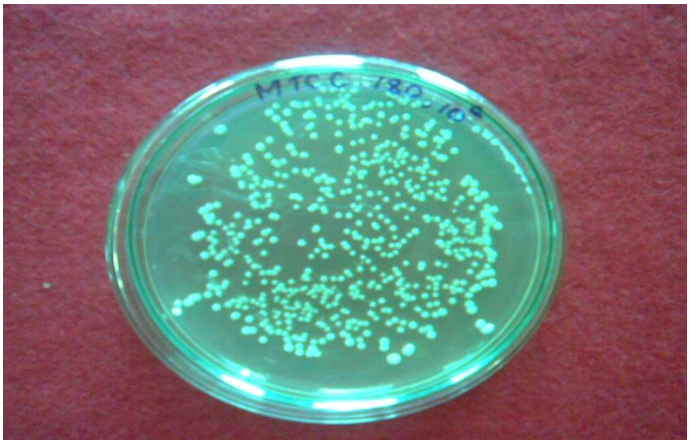


Plate 5. Population of MTCC 180 10^6 dilution

4. 1. 2. 1. Wine yield

The mean wine yield using pure strains and baker's yeast varied from 50.17 to 68.36 per cent (Figure 1). The highest wine yield was in T_7 {Baker's yeast, (10^6)} and the lowest in T_3 {MTCC 174, (10^6)}. Among pure strains, highest wine yield was for T_1 (59.53%).

On the basis of DMRT, wine yield of T_7 (68.36%) was significantly high and T_8 (67.76%) was on par with T_7. This was followed by the wine yield in T_1 (59.53%). T_2 (57.57%) showed no significant difference from T_1. Wine yield in T_5 (55.45%) was on par with T_2. Wine yield was the least in T_3 (50.17%) followed by T_4 (50.75%) and T_6 (51.75%). However, the differences between these treatments were not significant.

4. 1. 2. 2. Clarity

The mean clarity of eight banana wines using pure strains and baker's yeast varied from 54.83 to 78.92 per cent (Figure 2). Maximum wine clarity was found in T_5 {MTCC 180, (10^6)} and the least clarity was observed in T_7 {Baker's yeast, (10^6)}.

Application of DMRT revealed that wine clarity in T_5 (78.92%) and T_8 (78.75%) were significantly high when compared to other wines. Wine clarity in T_3 (70.25%) and T_6 (72.25%) were comparable without significant difference between them, but were significantly low when compared to T_5 and T_8. Wine clarity was significantly low in T_2 (57.33%), T_1 (55.92%) and T_7 (54.83%). However, the differences between these treatments were not significant.

4. 1. 2. 3. Alcohol content

The mean alcohol content of banana wines varied from 7.13 to 9.87 per cent (Figure 3). The highest alcohol content was found in T_4 {MTCC 174, (10^7)} and the least was in T_8 {Baker's yeast, (10^7)}.

Alcohol content in T_4 was significantly high when compared to other treatments. This was followed by T_3 (9.07%). Alcohol content in T_5 (8.80%) and T_2 (8.57%) were on par with T_3 without significant variation between them. T_8 showed

significantly low alcohol content among all the wines, but T_1 (8.33%), T_6 (8.00%) and T_7 (8.23%) were on par with T_8 without significant variation between them.

4. 1. 2. 4. pH

The mean pH of banana wines varied from 3.58 to 4.26 (Figure 4). The highest pH was found in T_4 {MTCC 174, (10^7)} and the lowest in T_2 {MTCC 172, (10^7)}.

On the basis of DMRT, pH of wines were significantly high in T_4 (4.26) and T_1 (4.25) but treatments T_3 (3.61), T_5 (3.84), T_6 (4.22), T_7 (3.74) and T_8 (3.93) were on par with T_4 and T_1 without significant difference between them.

4. 1. 2. 5. Titrable acidity

The mean titrable acidity of banana wines varied from 0.45 to 0.92 per cent (Figure 5). The highest acidity was found in T_3 {MTCC 174, (10^6)} and lowest in T_1 {MTCC 172, (10^6)}.

As per DMRT, T_3 (0.92%) showed significantly high titrable acidity but T_5 (0.85%) and T_7 (0.89%) were on par with T_3 without significant differences between them. Acidity was significantly low in T_1 (0.45%)

4. 1. 2. 6. TSS

The mean TSS of banana wines varied from 11.93 to 14.00^0 brix (Figure 6). The highest TSS was found in T_4 {MTCC 174, (10^7)} and lowest in T_3 {MTCC 174, (10^6)}.

As indicated by DMRT, TSS was significantly high in T_4 (14.00° Brix). TSS in T_1 (13.93° Brix), T_2 (13.67° Brix) and T_6 (13.60° Brix) were comparable to T_4 without significant difference between them. TSS was significantly low in T_3 (11.93° Brix) but T_5 (12.47° Brix), T_7 (12.46° Brix) and T_8 (12.33° Brix) were comparable to T_3 without significant differences between them.

Table 2. Effect of yeast strains on physico chemical qualities of banana wines

Physico chemical parameters						
Treatments	**Wine yield (%)**	**Clarity (%light transmittance)**	**Alcohol content (%)**	**pH**	**Titrable acidity (%)**	**TSS (^{0}Brix)**
T_1	59.53 ^{b}	55.92 ^{d}	8.33 ^{cde}	4.25 ^{a}	0.45 ^{e}	13.93 ^{a}
T_2	57.57 ^{bc}	57.33 ^{d}	8.57 ^{bcd}	3.58 ^{b}	0.62 ^{cd}	13.67 ^{ab}
T_3	50.17 ^{d}	70.25 ^{b}	9.07 ^{b}	3.61 ^{ab}	0.92 ^{a}	11.93 ^{c}
T_4	50.75 ^{d}	63.83 ^{c}	9.87 ^{a}	4.26 ^{a}	0.53 ^{d}	14.00 ^{a}
T_5	55.45 ^{c}	78.92 ^{a}	8.80 ^{bc}	3.84 ^{ab}	0.85 ^{ab}	12.47 ^{bc}
T_6	51.75 ^{d}	72.25 ^{b}	8.00 ^{de}	4.22 ^{ab}	0.64 ^{cd}	13.60 ^{ab}
T_7	68.36 ^{a}	54.83 ^{d}	8.23 ^{cde}	3.74 ^{ab}	0.89 ^{ab}	12.46 ^{bc}
T_8	67.76 ^{a}	78.75 ^{a}	7.13 ^{e}	3.93 ^{ab}	0.70 ^{c}	12.33 ^{bc}

Figure with even superscripts form a homogenous subset
Values are mean of 3 determinations

T_1 - MTCC 172 (10^6)

T_2 - MTCC 172 (10^7)

T_3 - MTCC 174 (10^6)

T_4 - MTCC 174 (10^7)

T_5 - MTCC 180 (10^6)

T_6 - MTCC 180 (10^7)

T_7 – Baker's yeast (10^6)

T_8 – Baker's yeast (10^7)

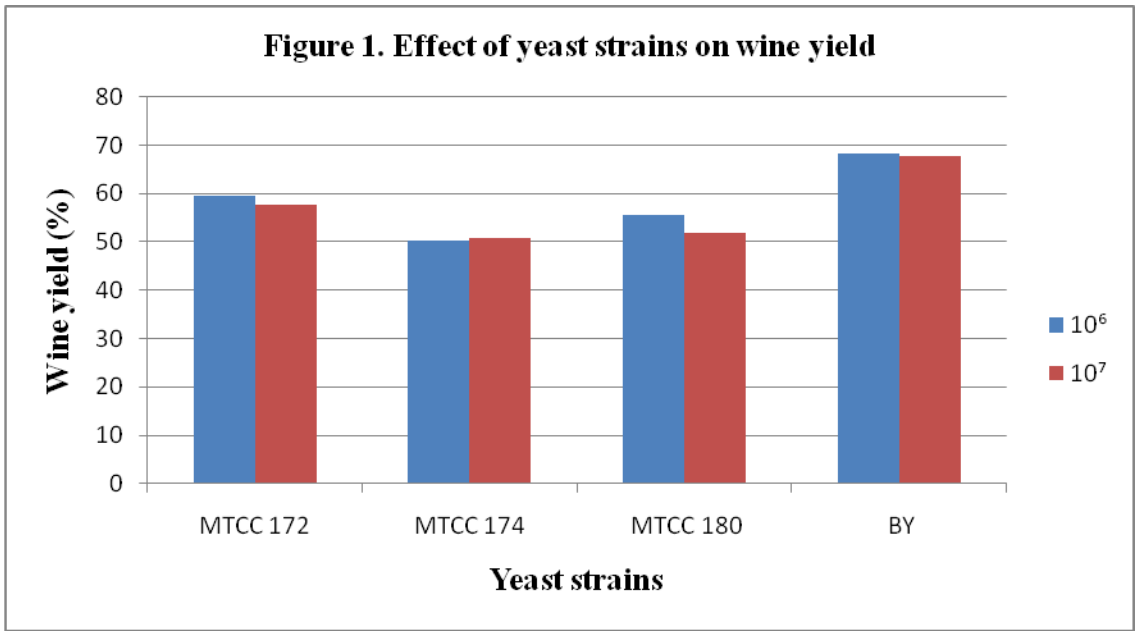


Figure 1. Effect of yeast strains on wine yield
Wine yield (%)
80
70
60
50
40
30
20
10
0
MTCC 172
MTCC 174
MTCC 180
BY
Yeast strains
10⁶
10⁷

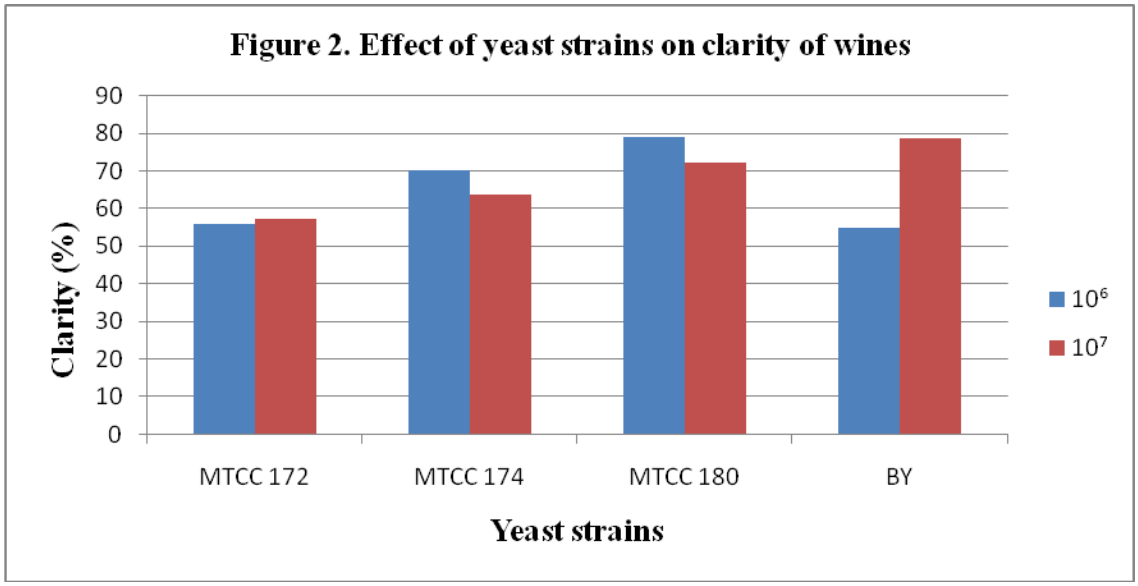


Figure 2. Effect of yeast strains on clarity of wines
Clarity (%)
90
80
70
60
50
40
30
20
10
0
MTCC 172
MTCC 174
MTCC 180
BY
Yeast strains
10⁶
10⁷

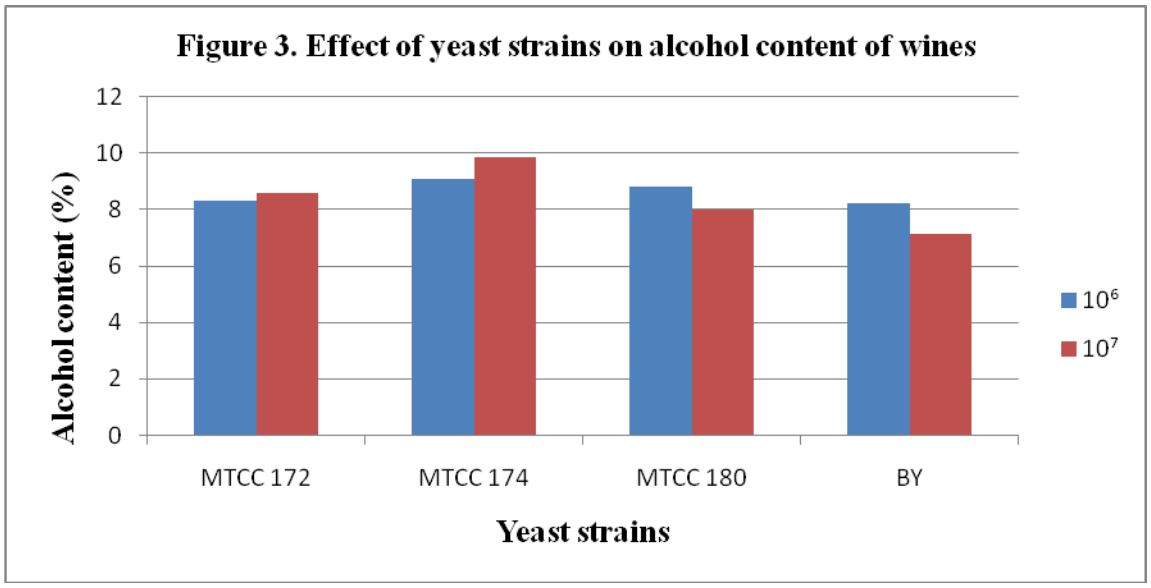


Figure 3. Effect of yeast strains on alcohol content of wines
Alcohol content (%)
12
10
8
6
4
2
0
MTCC 172
MTCC 174
MTCC 180
BY
Yeast strains
10⁶
10⁷

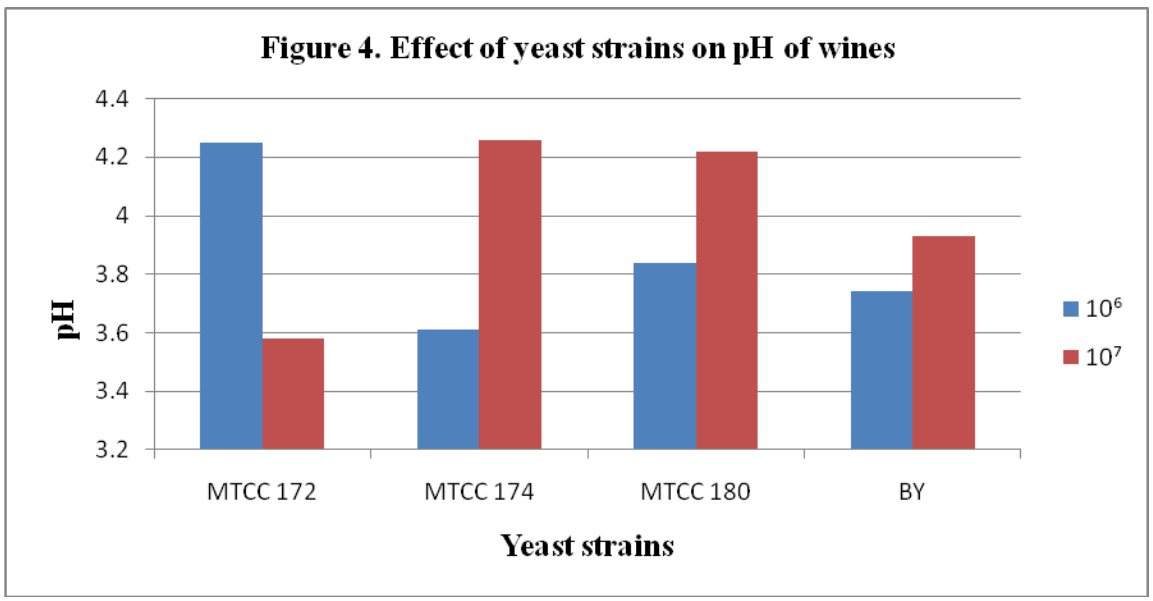


Figure 4. Effect of yeast strains on pH of wines
pH
4.4
4.2
4
3.8
3.6
3.4
3.2
MTCC 172
MTCC 174
MTCC 180
BY
Yeast strains
10⁶
10⁷

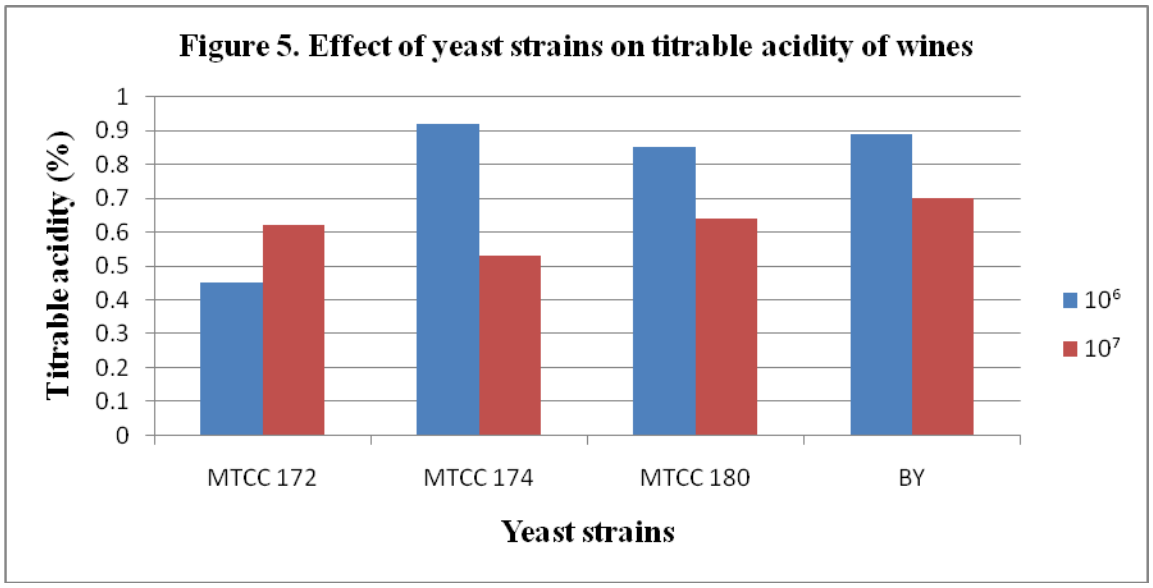


Figure 5. Effect of yeast strains on titrable acidity of wines
Titrable acidity (%)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
MTCC 172
MTCC 174
MTCC 180
BY
Yeast strains
10⁶
10⁷

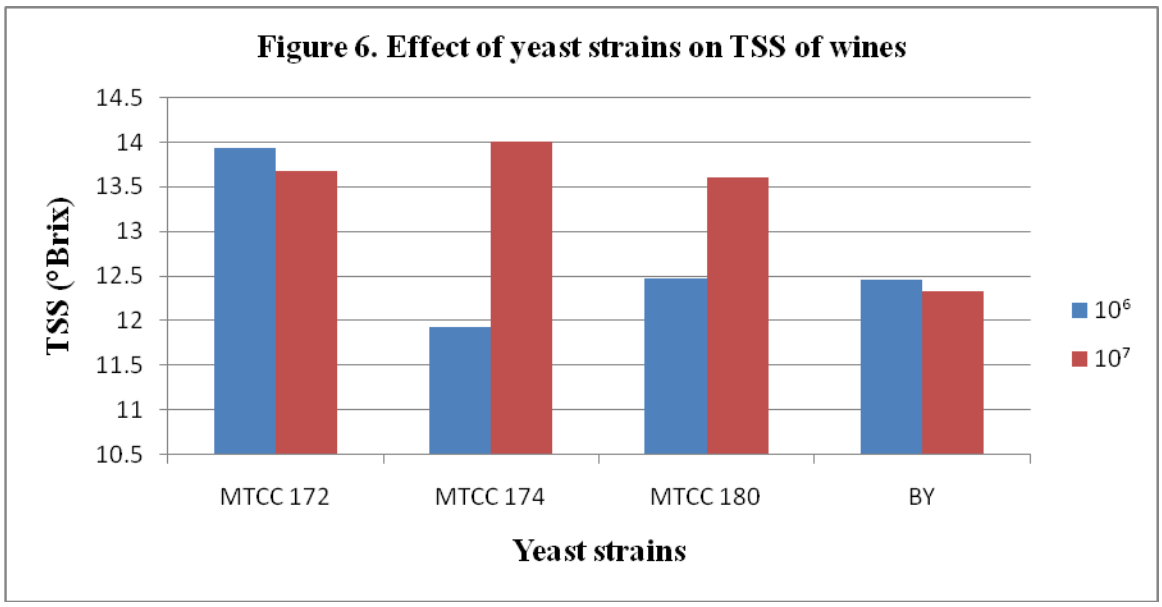


Figure 6. Effect of yeast strains on TSS of wines
TSS (°Brix)
14.5
14
13.5
13
12.5
12
11.5
11
10.5
MTCC 172
MTCC 174
MTCC 180
BY
Yeast strains
10⁶
10⁷

4. 1. 3. Sensory evaluation of banana wines prepared with pure strains and baker's yeast

The wines were prepared and poured in glass bottles. Freshly prepared wines were served in wine glasses for organoleptic evaluation by the selected panel of judges. Evaluation was carried out using a score card for different quality attributes like colour and appearance, flavour, desirable level of astringency, sugar acid blend, taste, acceptable level of alcohol strength and overall acceptability. Wines were ranked for different quality attributes based on their mean rank scores using Kendall's (W) test. The results of the organoleptic evaluation of the wines are presented in Table 3.

The highest score for colour and appearance of wines was in T_7 (8.4) and the lowest score was in T_6 (7.5). Among pure strain wines, maximum score for colour and appearance was for T_1 (8.1) and the lowest score was for T_6 (7.5).

Kendall's (W) test revealed that, the mean rank score for colour and appearance of the wines were varied without an agreement among the panelists.

Highest score for flavour was 8.2 and the lowest was 7.3 for the treatments T_7 and T_3 respectively. Among pure strain wines, mean score for flavour was maximum (8.1) in T_1 {MTCC 172, (10^6)} and the least score (7.3) was in T_3 {MTCC 174, (10^6)}. Among all the wines, maximum score for flavour (8.2) was for the wine with baker's yeast (10^6).

The panelists were in an agreement with the highest flavour profile in T_7 with a mean rank score of 5.95. This was followed by the flavour profile in T_1 with a mean rank score of 5.70.

The maximum score for the desirable level of astringency was in T_5 and T_6 (7.4), the lowest score was in T_4 (6.6). Among pure strain wines, mean score for the desirable level of astringency was found to be maximum (7.4) in T_5 and T_6 {MTCC 180, (10^6 and 10^7)} and the least score (6.6) was for T_4 {MTCC 174, (10^7)}. Among the wines with baker's yeast, the mean score was same (7.2) for T_7 and T_8. The judges

were not in an agreement in the desirable level of astringency of wines as shown by the mean rank scores of Kendall's (W) test.

The mean score for sugar acid blend ranged from 7.4 to 7.8, the maximum being in T_3. Among pure strain wines, mean score for sugar acid blend was highest (7.8) in T_3 {MTCC 174, (10^6)} and the lowest score (7.4) was for T_6 {MTCC 180, (10^7)}. Among the wines with baker's yeast, mean score for sugar acid blend was high (7.6) in T_7 compared to T_8 which had a mean score of 7.5. The mean rank score of Kendall's (W) test showed that the panelists were not in an agreement with this character also.

The mean score for taste was found to be maximum in T_1 and T_4 (7.9) and the least in T_3 (7.3). Among pure strain wines, mean score for taste was highest (7.9) in T_1 {MTCC 172, (10^6)} and T_4 {MTCC 174, (10^7)}.and the least score for taste (7.3) was for T_3 {MTCC 174, (10^6)}. Among wines with baker's yeast, mean score for taste was high (7.8) in T_7 (10^6). Kendall's (W) test showed that the mean rank score for taste also varied without an agreement among the panelists.

The mean score for the acceptable level of alcohol strength was maximum in T_4 (7.9) and the lowest score was in T_1 and T_8 (7.0). Among pure strain wines, mean score for the acceptable alcohol strength was high (7.9) in T_4 {MTCC 174, (10^6)} and the least score for the acceptable level of alcohol strength was in T_1 (7.0). Among wines with baker's yeast, mean score for acceptable alcohol strength was more (7.6) in T_7 (10^6). As revealed by the mean rank score of Kendall's (W) test, the acceptable level of alcohol strength also varied without an agreement among the panelists.

The mean score for overall acceptability varied from 7.2 to 7.8 (Figure 7). The highest mean score was for T_1 and the least score was for T_4 and T_8 (7.2). Among pure strain wines, the mean score for overall acceptability was maximum (7.8) in T_1 {MTCC 170, (10^6)} and the least score (7.2) was for T_4 {MTCC 180, (10^7)}. Among wines with baker's yeast, T_7 (10^7) showed a better overall acceptability score (7.6).

4. 1. 4. Selection of yeast strains with the most acceptable wines

Two yeast strains were selected from the eight treatments for further studies. Based on the overall acceptability of wines, T_1 {MTCC 172, (10^6)} was selected from

Table 3. Mean score for organoleptic qualities of wines with yeast strains

Treat-ments	Character						
	Colour and appearance	Flavour	Astringe-ncy	Sugar acid blend	Taste	Alcohol strength	Overall acceptability
T_1	8.1 (5.25)	8.1 (5.70)	7.0 (4.10)	7.6 (4.70)	7.9 (5.30)	7.0 (3.10)	7.8 (5.55)
T_2	7.8 (4.55)	7.6 (4.20)	7.2 (4. 60)	7.5 (4.35)	7.6 (4.35)	7.7 (5.10)	7.4 (4.60)
T_3	7.6 (3.70)	7.3 (3.00)	7.1 (4. 45)	7.8 (5.30)	7.3 (3.35)	7.6 (4.85)	7.4 (4.60)
T_4	7.9 (4.60)	7.5 (3.70)	6.6 (3.25)	7.6 (4.65)	7.9 (5.40)	7.9 (5.65)	7.2 (3.80)
T_5	7.7 (4.05)	7.7 (4.50)	7.4 (5.05)	7.5 (4.25)	7.7 (4.65)	7.5 (4.50)	7.4 (4.65)
T_6	7.5 (3.35)	7.7 (4.65)	7.4 (5.10)	7.4 (3.85)	7.5 (4.10)	7.5 (4.65)	7.3 (4.15)
T_7	8.4 (6.15)	8.2 (5.95)	7.2 (4.65)	7.6 (4.60)	7.8 (5.00)	7.6 (5.00)	7.6 (5.00)
T_8	7.8 (4.35)	7.6 (4.30)	7.2 (4.55)	7.5 (4.30)	7.5 (3.85)	7.0 (3.15)	7.2 (3.65)
Kendall's W value	18.5 ^{NS}	20.6 *	7.6 ^{NS}	4.1 ^{NS}	13.5^{NS}	17.6 ^{NS}	8.6 ^{NS}

Figures in parenthesis are mean rank score * - 5% significance NS – Not Significant

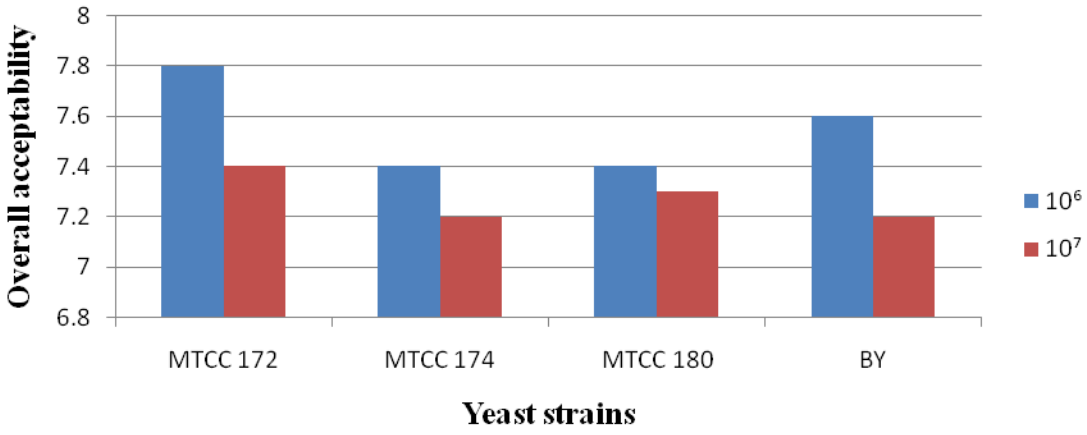
T_1 - MTCC 172 (10^6) T_2 - MTCC 172 (10^7)

T_3 - MTCC 174 (10^6) T_4 - MTCC 174 (10^7)

T_5 - MTCC 180 (10^6) T_6 - MTCC 180 (10^7)

T_7 – Baker's yeast (10^6) T_8 – Baker's yeast (10^7)

Figure 7. Mean score for overall acceptability of wines with yeast strains



the pure strains which had the highest mean score for overall acceptability (7.8) and T_7 {Baker's yeast, (10^6)} was selected from baker's yeast which had the highest score of 7.6 for overall acceptability.

4. 2. Effect of treatments on the quality of banana wines with selected yeast strains

Pure strain MTCC 172 (10^6) and baker's yeast (10^6), standardised in the previous experiment were selected for wine development. Wines were developed by treating banana pulp with the enzyme pectinase, potassium metabisulphite and also by pressure cooking the pulp for five minutes. Wines were developed with the selected pure strain and baker's yeast.

4. 2. 1. Effect of treatments on the physico chemical attributes of banana wines

The banana wines prepared by different treatments were evaluated for different parameters like wine yield, clarity, alcohol content, pH, titrable acidity and TSS and is presented in Table 4 (a) and 4 (b). Effect of selected yeast strains on the above physico chemical parameters of wines prepared by each treatment were compared and is presented in Table 5(a), Table 5(b) and Table 5(c).

4. 2. 1. 1. Wine yield

The wine yield of banana wines prepared by different treatments using the selected pure strain {MTCC 172, (10^6)} and baker's yeast (10^6) are presented in Table 4 (a).

The mean wine yield of banana wines prepared by the selected pure strain varied from 59.53 to 70.43 per cent (Figure 8). The highest wine yield was found in T_7 and the lowest in T_1. On the basis of DMRT, the mean wine yield in T_7 was significantly high when compared to T_1. In all other treatments, the wine yield was comparable to that of T_7 without significant difference between them.

The mean wine yield of banana wines prepared by different treatments using baker's yeast varied from 64.03 to 81.94 per cent (Figure 8). The highest wine yield was found in T_4 and lowest in T_7. DMRT showed that wine yield in T_4 was significantly high and wine yield in T_2 (78.28%) was comparable to that in T_4. Wine

yield in T_6 (71.36%), T_3 (70.61%) and T_5 (69.27%) did not show any significant differences between them and were also on par with T_2. Wine yield in T_7 (64.03%) was significantly low when compared to wine yield in other treatments.

Wines prepared by each treatment with the selected pure strain and baker's yeast were compared for their wine yield by applying paired 't' test and is presented in Table 5(a). The wine yield prepared by the pure strain and baker's yeast differed significantly except in T_5, T_6 and T_7. In all other treatments, wine yield was significantly high with baker's yeast irrespective of the treatments.

4. 2. 1. 2. Clarity

The clarity of banana wines prepared by different treatments using the selected pure strain {MTCC 172 (10^6)} and baker's yeast (10^6) are presented in Table 4 (a) and (Figure 9).

The clarity of banana wines prepared with the pure strain subjected to various treatments varied from 53.50 to 83.93 per cent. Maximum clarity was observed in T_8 and the least was in T_3. DMRT revealed that wine with maximum clarity T_8 showed no significant variation with T_6 (82.75%) and T_4 (81.92%). Followed by this, T_2 (75.83%) showed significant clarity when compared to the other treatments.

The clarity of banana wines prepared with baker's yeast, subjected to various treatments varied from 53.67 to 86.08 per cent. Maximum clarity was observed in T_6 and the least clarity was in T_5. The maximum wine clarity in T_6 showed no significant variation with the wine clarity in T_8 (84.75%). T_2 (80.58%) showed the next highest clarity and T_4 (80.25%) was on par with T_2 without significant difference between them.

Wines prepared by each treatment with the selected pure strain and baker's yeast were compared for their clarity by applying paired 't' test and is presented in Table 5(a). The clarity of banana wines prepared by the pure strain and baker's yeast did not have any significant difference in all the treatments.

4. 2. 1. 3. Alcohol content

The alcohol content of banana wines prepared by different treatments using the pure strain {MTCC 172, (10^6)} and baker's yeast (10^6) are presented in Table 4 (a) and (Figure 10).

The mean alcohol content of banana wines prepared by the pure strain varied from 8.13 to 10.26 per cent. Maximum alcohol content was in T_6 and the least was in T_5. DMRT showed that the alcohol content in T_6 was significantly high when compared with the other treatments. Followed by this, T_2 (9.40%) had significantly high alcohol content but T_7 (9.17%) was on par with T_2 without significant variation among them. The alcohol content in T_8 (8.16%), T_3 (8.53%) and T_1 (8.33%) were on par with T_5 with the least alcohol content.

The mean alcohol content of banana wines prepared by different treatments using baker's yeast varied from 8.00 to 10.16 per cent. Alcohol content was significantly high in T_5 (10.16%) and T_6 (9.73%) was on par with T_5. All other treatments showed no significant variation in the alcohol content of wines among themselves.

Wines prepared by each treatment with the selected pure strain and baker's yeast were compared for their alcohol content by applying paired 't' test and is presented in Table 5(b). As revealed in the Table, the mean alcohol content of banana wines prepared by the pure strain {MTCC 172 (10^6)} and baker's yeast (10^6) did not show any significant difference in all the treatments.

4. 2. 1. 4. pH

The pH of banana wines prepared by different treatments using the pure strain {MTCC 172, (10^6)} and baker's yeast (10^6) are presented in Table 4 (b).

The pH of banana wines prepared with pure strain subjected to various treatments, varied from 3.87 to 4.60. Maximum pH was in T_5 and the lowest pH in T_7 (Figure 11). DMRT indicated no significant difference in wine pH with the pure strain.

Table 4 (a). Effect of treatments and yeast strains on physico chemical parameters of wines

Physico chemical parameters						
Treatments	**Wine yield (%)**		**Clarity (%)**		**Alcohol content (%)**	
	PS	BY	PS	BY	PS	BY
T_1	59.53 ^{bc}	68.36 ^{c}	55.92 ^{de}	54.83 ^{d}	8.33 ^{e}	8.23 ^{b}
T_2	64.76 ^{ab}	78.28 ^{ab}	75.83 ^{b}	80.58 ^{b}	9.40 ^{b}	8.13 ^{b}
T_3	65.78 ^{ab}	70.61 ^{b}	53.50 ^{ef}	63.00 ^{c}	8.53 ^{de}	8.00 ^{b}
T_4	66.78 ^{ab}	81.94 ^{a}	81.92 ^{a}	80.25 ^{b}	8.80 ^{cd}	8.00 ^{b}
T_5	65.95 ^{ab}	69.27 ^{b}	58.58 ^{cd}	53.67 ^{d}	8.13 ^{e}	10.16 ^{a}
T_6	65.79 ^{ab}	71.36 ^{b}	82.75 ^{a}	86.08 ^{a}	10.26 ^{a}	9.73 ^{a}
T_7	70.43 ^{a}	64.03 ^{d}	62.75 ^{c}	55.42 ^{d}	9.17 ^{bc}	8.03 ^{b}
T_8	60.66 ^{ab}	68.19 ^{c}	83.93 ^{a}	84.75 ^{a}	8.16 ^{e}	8.10 ^{b}

Figures with same superscripts form a homogenous subset

DMRT column wise comparison

Values are mean of 3 determinations

PS – Pure strain BY – Baker's yeas

T_1 - Pulp + Sugar + PS/BY (control)
T_2 - Pulp + Sugar + PS/BY + pectinase
T_3 - Pulp + Sugar + PS/BY + KMS
T_4 - Pulp + Sugar + PS/BY + pectinase + KMS
T_5 - Pressure cooked pulp + Sugar + PS/BY
T_6 - Pressure cooked pulp + Sugar + PS/BY + pectinase
T_7 - Pressure cooked pulp + Sugar + PS/BY + KMS
T_8 - Pressure cooked pulp + Sugar + PS/BY + pectinase + KMS

Figure 8. Effect of treatments and yeast strains on wine yield

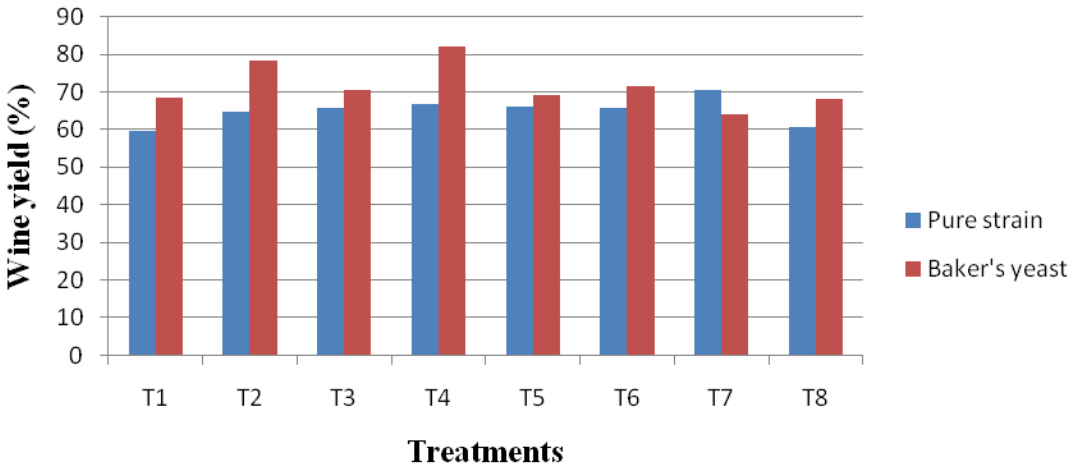


Figure 9. Effect of treatments and yeast strains on wine clarity

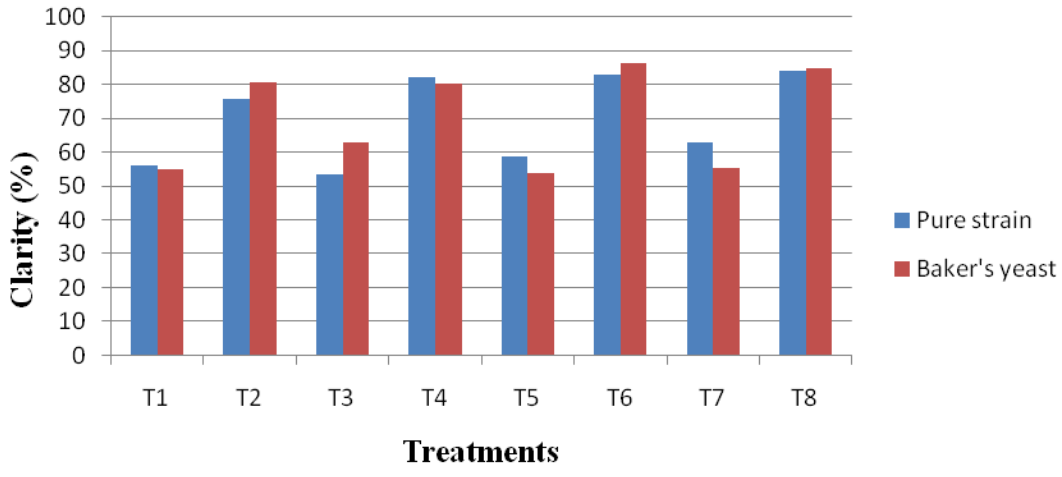
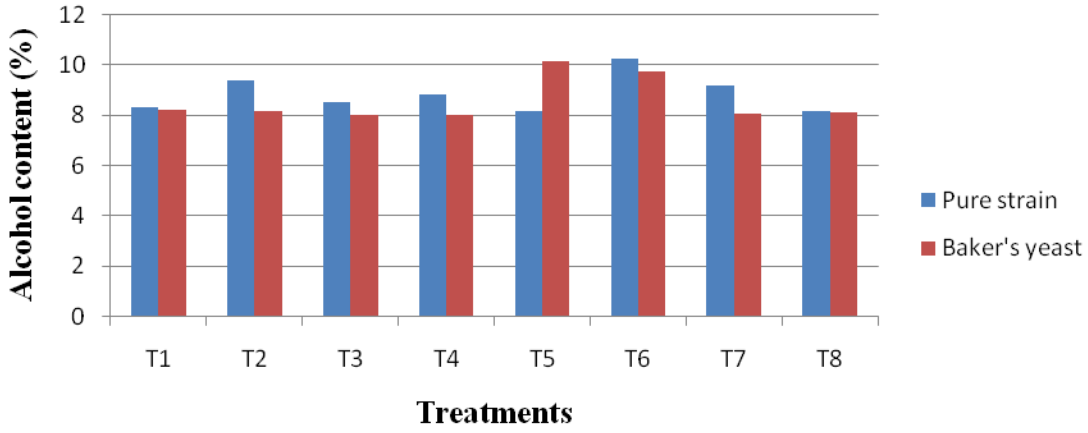


Figure 10. Effect of treatments and yeast strains on alcohol content of wines



The mean pH of banana wines prepared by baker's yeast was maximum in T_4 (4.33) and minimum in T_5 (3.55) (Figure 11). As indicated by DMRT, pH was significantly high in T_4 and all other treatments except T_5 (3.55) were on par with T_4 without significant variation among them.

Wines prepared by each treatment with the selected pure strain and baker's yeast were compared for their pH by applying paired 't' test and is presented in Table 5(b). As shown in the Table, there was no significant difference in the pH of the wines prepared by the selected pure strain and baker's yeast in treatments T_1, T_2, T_4 and T_7. In T_3, T_5, T_6 and T_8, pH of the wines prepared by baker's yeast were significantly low when compared with the wines prepared with the selected pure strain.

4. 2. 1. 5. Titrable acidity

The titrable acidity of banana wines prepared by different treatments using the pure strain {MTCC 172, (10^6)} and baker's yeast (10^6) are presented in Table 4(b) and (Figure 12).

The mean titrable acidity of banana wines prepared by pure strain varied from 0.41 to 0.55 per cent. Maximum acidity was in T_2 and T_6 and the lowest in T_4. Significant variation in titrable acidity was observed only between the highest and lowest titrable acidity.

The mean titrable acidity of banana wines prepared by baker's yeast, varied from 0.43 to 0.94 per cent. Maximum acidity was in T_5 and the lowest in T_2 and T_7. Even though T_5 showed the maximum acidity, T_6 (0.92%) and T_1 (0.89%) showed no significant variation from T_5. All other treatments showed significantly low titrable acidity without significant variation between them.

Wines prepared by each treatment with the selected pure strain and baker's yeast were compared for their titrable acidity by applying paired 't' test and is presented in Table 5(c). As revealed in the Table, the mean titrable acidity of banana wines prepared by the selected pure strain and baker's yeast did not show any significant difference except in T_1, T_5 and T_6. The titrable acidity of wines prepared by baker's yeast in these treatments were significantly high when compared with wines with pure strain.

4. 2. 1. 6. TSS

The TSS of banana wines prepared by different treatments using the pure strain {MTCC 172, (10^6)} and baker's yeast (10^6) are presented in Table 4(b) and (Figure 13).

The mean TSS of wines prepared with the pure strain varied from 13.43 to 14.60^0 Brix. Maximum TSS was found in T_8 and the lowest in T_6. As indicated by DMRT there was no significant variation in the TSS content of wines with treatments.

In wines with baker's yeast, TSS varied from 11.73 to 14.23^0 Brix. Maximum TSS was in T_4 and the lowest in T_6. TSS in T_4 showed no significant variations with T_3 (14.00° Brix), T_7 (13.93° Brix) and T_2 (13.70° Brix). Significantly low TSS was observed in T_6 (11.73° Brix) and T_5 (12.86° Brix).

Wines prepared by each treatment with the selected pure strain and baker's yeast were compared for their TSS by applying paired 't' test and is presented in Table 5(c). As shown in the Table, the mean TSS of banana wines did not show any significant difference, except in T_8. The TSS of wine prepared by baker's yeast in treatment T_8, was significantly low when compared with the wine prepared with the selected pure strain.

4. 2. 2. Effect of treatments on the organoleptic qualities of banana wines with selected yeast strains

The wines were prepared and poured in glass bottles. Freshly prepared wines were served in wine glasses for organoleptic evaluation by the selected panel of judges. Organoleptic evaluation was carried out using score card for different quality attributes like colour and appearance, flavour, desirable level of astringency, sugar acid blend, taste, acceptable level of alcohol strength and overall acceptability. Wines were ranked for different quality attributes based on their mean rank scores using Kendall's (W) test. The results of the organoleptic evaluation of the wines are presented in Table 6 and 7.

As shown in Table 6, the mean score for colour and appearance of the wines varied from 7.2 to 8.3. Maximum score was for T_6 and the least score for T_5. The

Table 4 (b). Effect of treatments and yeast strains on physico chemical parameters of wines

Physico chemical parameters						
Treatments	**pH**		**Titrable acidity (%)**		**TSS (^{0}Brix)**	
	PS	BY	PS	BY	PS	BY
T_1	4.25 ^{a}	3.74 ^{ab}	0.44 ^{ab}	0.89 ^{a}	13.93 ^{a}	12.46 ^{b}
T_2	3.96 ^{a}	4.01 ^{ab}	0.55 ^{a}	0.43 ^{b}	13.60 ^{a}	13.70 ^{a}
T_3	4.45 ^{a}	4.16 ^{ab}	0.43 ^{ab}	0.45 ^{b}	13.96 ^{a}	14.00 ^{a}
T_4	4.22 ^{a}	4.33 ^{a}	0.41 ^{b}	0.47 ^{b}	13.83 ^{a}	14.23 ^{a}
T_5	4.60 ^{a}	3.55 ^{bc}	0.45 ^{ab}	0.94 ^{a}	14.10 ^{a}	12.86 ^{c}
T_6	3.95 ^{a}	3.64 ^{ab}	0.55 ^{a}	0.92 ^{a}	13.43 ^{a}	11.73 ^{c}
T_7	3.87 ^{a}	4.24 ^{ab}	0.51 ^{ab}	0.43 ^{b}	13.70 ^{a}	13.93 ^{a}
T_8	4.42 ^{a}	3.71 ^{ab}	0.45 ^{ab}	0.53 ^{b}	14.60 ^{a}	12.86 ^{b}

Figures with same superscripts form a homogenous subset

DMRT column wise comparison

Values are mean of 3 determinations

PS – Pure strain BY – Baker's yeast

T_1 - Pulp + Sugar + PS/BY (control)
T_2 - Pulp + Sugar + PS/BY + pectinase
T_3 - Pulp + Sugar + PS/BY + KMS
T_4 - Pulp + Sugar + PS/BY + pectinase + KMS
T_5 - Pressure cooked pulp + Sugar + PS/BY
T_6 - Pressure cooked pulp + Sugar + PS/BY + pectinase
T_7 - Pressure cooked pulp + Sugar + PS/BY + KMS
T_8 - Pressure cooked pulp + Sugar + PS/BY + pectinase + KMS

Table 5 (a). Comparison of treatments and yeast strain on yield and clarity of wines

Physico chemical parameters						
Treatments	**Wine yield (%)**			**Clarity (%)**		
	Mean ± SD		**t-value**	**Mean ± SD**		**t- value**
	PS	**BY**		**PS**	**BY**	
T_1	59.53 ± 1.65	68.36 ± 4.00	6.19 **	55.92 ± 2.19	54.33 ± 3.14	0.84 NS
T_2	64.76 ± 2.61	78.28 ± 8.21	4.70 **	75.83 ± 2.94	80.58 ± 2.49	3.28 NS
T_3	65.78 ± 2.18	70.61 ± 7.01	1.97 **	53.50 ± 3.61	63.00 ± 3.44	5.71 NS
T_4	66.78 ± 2.24	81.94 ± 5.57	7.57 **	81.92 ± 3.96	80.25 ± 3.52	1.41 NS
T_5	65.95 ± 8.66	69.27 ± 6.99	0.89 NS	58.58 ± 2.83	53.67 ± 2.63	3.82 NS
T_6	65.79 ± 6.49	71.36 ± 4.62	2.09 NS	82.75 ± 2.99	86.08 ± 3.45	2.73 NS
T_7	70.43 ± 8.59	64.03 ± 5.25	4.88 NS	62.75 ± 4.44	55.42 ± 2.89	4.15 NS
T_8	60.66 ± 4.03	68.19 ± 7.17	2.74 *	83.93 ± 2.38	84.75 ± 2.14	2.49 NS

PS – Pure strain (MTCC 172) BY – Baker's yeast

** - significant at 1% * - significant at 5% NS - Not Significant

T_1 - Pulp + Sugar + PS/BY (control)
T_2 - Pulp + Sugar + PS/BY + pectinase
T_3 - Pulp + Sugar + PS/BY + KMS
T_4 - Pulp + Sugar + PS/BY + pectinase + KMS
T_5 - Pressure cooked pulp + Sugar + PS/BY
T_6 - Pressure cooked pulp + Sugar + PS/BY + pectinase
T_7 - Pressure cooked pulp + Sugar + PS/BY + KMS
T_8 - Pressure cooked pulp + Sugar + PS/BY + pectinase + KMS

Table 5 (b). Comparison of treatments and yeast strains on alcohol content and pH of wines

Physico chemical parameters						
Treatments	Alcohol content (%)			pH		
	Mean ± SD		t- value	Mean ± SD		t- value
	PS	BY		PS	BY	
T_1	8.33 ± 0.23	8.23 ± 0.33	0.72^{NS}	4.25 ± 0.53	3.74 ± 0.25	2.58 ^{NS}
T_2	9.40 ± 0.22	8.13 ± 0.26	10.74 ^{NS}	3.96 ± 0.48	4.01 ± 0.42	0.23 ^{NS}
T_3	8.53 ± 0.32	8.00 ± 0.32	3.53 ^{NS}	4.45 ± 0.55	4.16 ± 0.53	1.13 *
T_4	8.80 ± 0.23	8.00 ± 0.26	6.65 ^{NS}	4.22 ± 0.38	4.33 ± 0.43	0.54 ^{NS}
T_5	8.13 ± 0.31	10.16 ± 0.30	14.08 ^{NS}	4.60 ± 0.44	3.55 ± 0.37	5.49 **
T_6	10.26 ± 0.23	9.73 ± 0.18	5.40 ^{NS}	3.95 ± 0.11	3.64 ± 0.21	3.90 **
T_7	9.17 ± 0.23	8.03 ± 0.24	10.13 ^{NS}	3.87 ± 0.19	4.24 ± 0.25	3.43 ^{NS}
T_8	8.16 ± 0.22	8.10 ± 0.31	0.52 ^{NS}	4.42 ± 0.39	3.71 ± 0.22	4.74 *

PS – Pure strain (MTCC 172) BY – Baker's yeast

** - significant at 1% * - significant at 5% NS - Not Significant

T_1 - Pulp + Sugar + PS/BY (control)
T_2 - Pulp + Sugar + PS/BY + pectinase
T_3 - Pulp + Sugar + PS/BY + KMS
T_4 - Pulp + Sugar + PS/BY + pectinase + KMS
T_5 - Pressure cooked pulp + Sugar + PS/BY
T_6 - Pressure cooked pulp + Sugar + PS/BY + pectinase
T_7 - Pressure cooked pulp + Sugar + PS/BY + KMS
T_8 - Pressure cooked pulp + Sugar + PS/BY + pectinase + KMS

Table 5 (c). Comparison of treatments and yeast strains on acidity and TSS of wines

Physico chemical parameters						
Treatments	**Titrabe acidity (%)**			**TSS (^{0}Brix)**		
	Mean ± SD		**t- value**	**Mean ± SD**		**t- value**
	PS	**BY**		**PS**	**BY**	
T_1	0.44 ± 0.07	0.89 ± 0.08	11.09 **	13.93 ± 0.43	12.47 ± 0.47	6.89 NS
T_2	0.55 ± 0.08	0.43 ± 0.06	3.62 NS	13.60 ± 0.62	13.70 ± 0.21	0.46 NS
T_3	0.43 ± 0.08	0.45 ± 0.07	0.55 NS	13.96 ± 0.29	14.00 ± 0.26	0.26 NS
T_4	0.41 ± 0.06	0.47 ± 0.05	1.95 NS	13.83 ± 0.35	14.23 ± 0.34	2.46 NS
T_5	0.45 ± 0.11	0.94 ± 0.08	10.84 **	14.10 ± 0.57	12.86 ± 0.82	4.10 NS
T_6	0.55 ± 0.06	0.92 ± 0.09	9.81 **	13.43 ± 0.39	11.73 ± 0.27	10.69 NS
T_7	0.51 ± 0.07	0.43 ± 0.08	2.22 NS	13.70 ± 0.21	13.93 ± 0.20	1.72 NS
T_8	0.45 ± 0.07	0.53 ± 0.10	2.00 NS	14.60 ± 0.28	12.86 ± 0.77	4.39 **

PS – Pure strain (MTCC 172) BY – Baker's yeast

** - significant at 1% NS - Not Significant

T_1 - Pulp + Sugar + PS/BY (control)
T_2 - Pulp + Sugar + PS/BY + pectinase
T_3 - Pulp + Sugar + PS/BY + KMS
T_4 - Pulp + Sugar + PS/BY + pectinase + KMS
T_5 - Pressure cooked pulp + Sugar + PS/BY
T_6 - Pressure cooked pulp + Sugar + PS/BY + pectinase
T_7 - Pressure cooked pulp + Sugar + PS/BY + KMS
T_8 - Pressure cooked pulp + Sugar + PS/BY + pectinase + KMS

Figure 11. Effect of treatments and yeast strains on wine pH

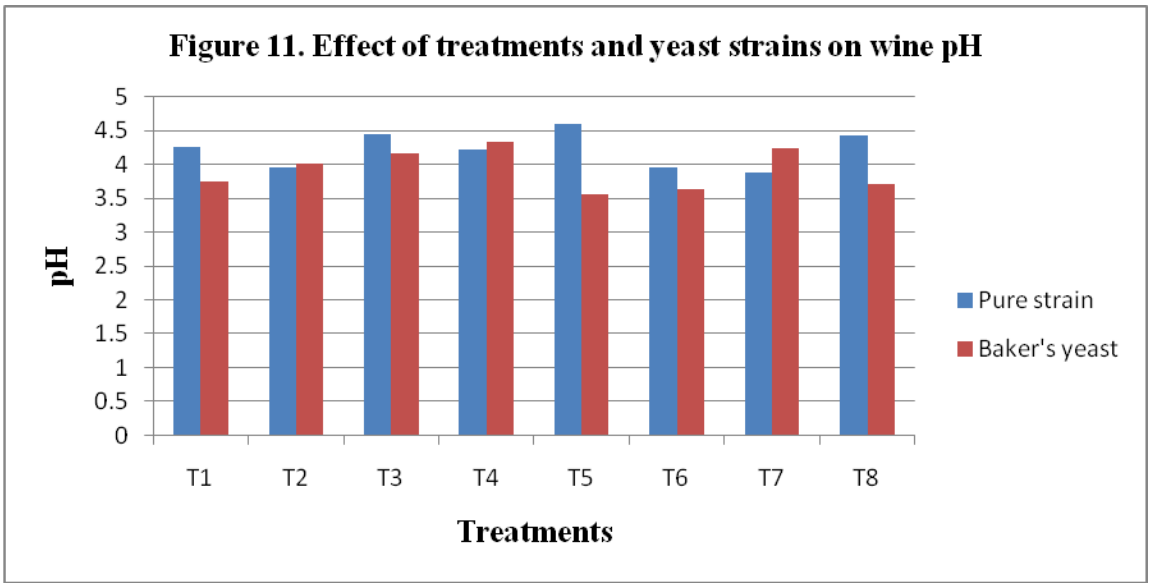


Figure 12. Effect of treatments and yeast strains on acidity of wines

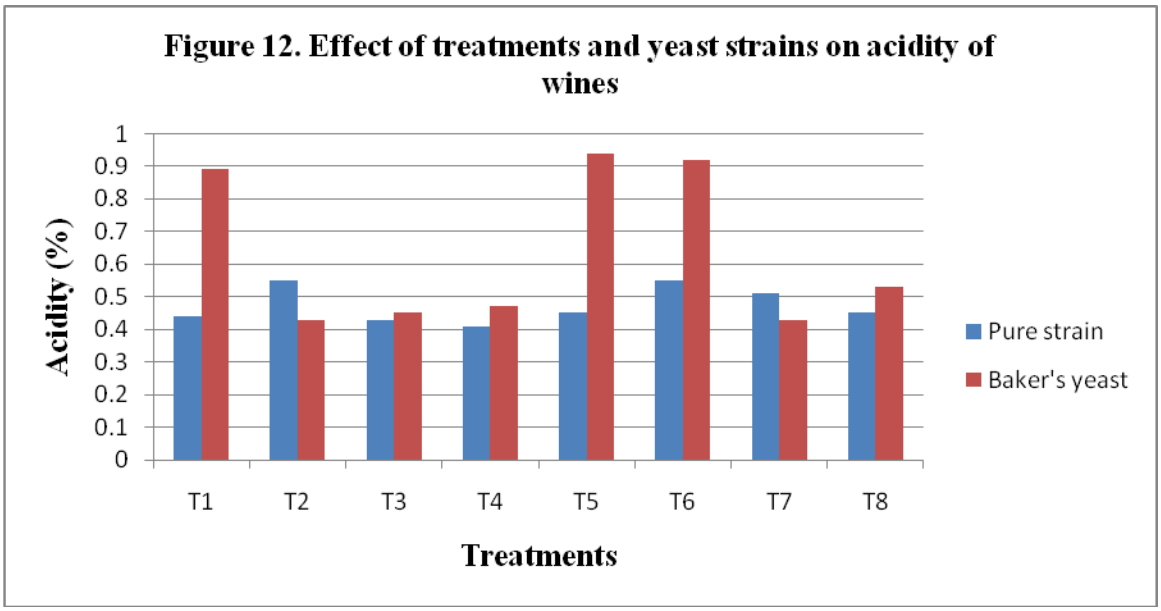


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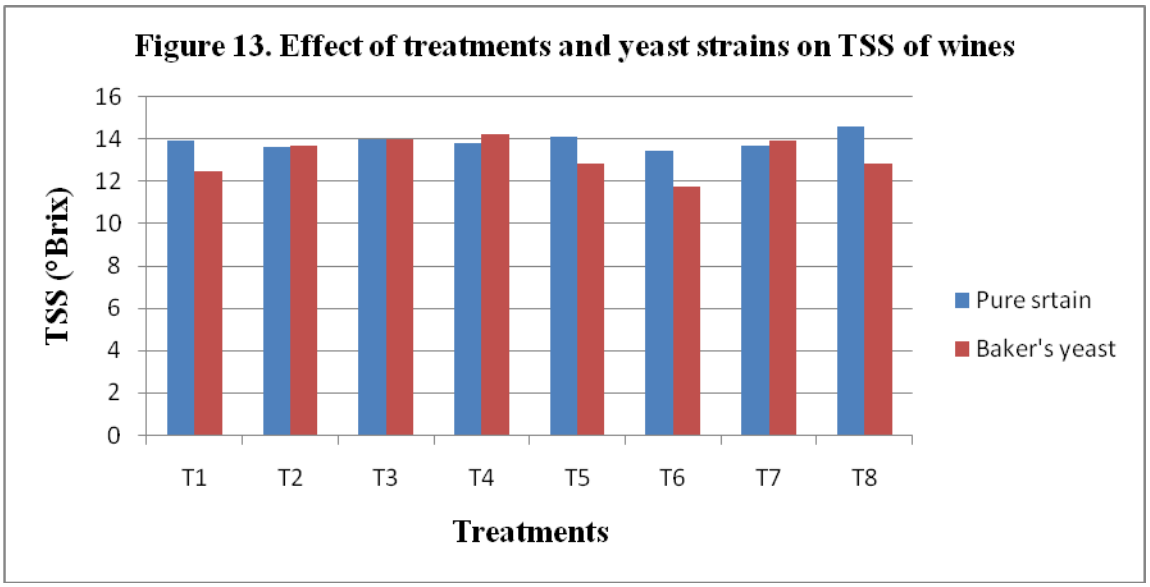
Figure 13. Effect of treatments and yeast strains on TSS of wines



highest rank score of 6.25 in T_6 followed by 5.50 in T_1 revealed an agreement of the judges regarding this quality attribute of the wines.

The highest mean score for flavour was in T_1 (8.1) and the lowest mean score was in T_5 (7.1). The rank score by Kendall's (W) test revealed that the judges were not in an agreement with regards to the flavour of the wines. The mean score for desirable level of astringency of the wines prepared by the pure strain varied from 6.1 to 7.0. Maximum score was for T_1 and the lowest score was for T_5 and T_7. The judges were found to be in an agreement with this quality of the wines.

The mean score for sugar acid blend of the wines prepared by the pure strain varied from 7.3 to 7.9 for the treatments. Maximum score was for T_2 and the lowest score was for T_5. The mean score for taste of banana wines prepared by different treatments with the selected pure strain varied from 7.1 to 7.9. Maximum score was for T_1 and T_2 and the lowest score was for T_7. The judges were not in an agreement with regard to the sugar acid blend and taste of the wines. The mean score for acceptable level of alcohol strength of the wines prepared by different treatments with the pure strain showed the highest score in T_2 (7.9) and the lowest score in T_1 and T_3 (7.0). The high rank score of 5.50 for T_2 followed by 5.00 in T_8 showed an agreement with regards to the acceptable level of alcohol strength in wines. The mean score for overall acceptability of wines prepared by different treatments with the selected pure strain varied from 7.2 to 7.9 (Figure 14). The highest mean score was T_2 and T_8 in and the minimum score was in T_5.

As revealed in Table 7, the colour and appearance of the wines prepared by different treatments with baker's yeast (10^6) varied from 7.8 to 8.4. The maximum score was for T_1 and the lowest score was for T_7. The mean score for flavour of the wines varied from 6.9 to 8.2. Maximum score for flavour was for T_1 and the lowest score for T_8. The mean score for desirable level of astringency varied from 6.3 to 7.2. The maximum score was for T_1 and the lowest score was for T_2. The mean score for sugar acid blend varied from 7.0 to 7.6. The maximum score was for T_1 and the lowest score was for T_8. The mean score for taste varied from 6.7 to 7.8 among treatments. Maximum score for taste was for T_1 and T_4 and the lowest score was for T_8. Mean score for the acceptable level of alcohol strength varied from 7.3 to 8.0 maximum for T_5 and lowest in T_8. Overall acceptability of wines prepared by the

selected baker's yeast showed a maximum mean score for T_2 (7.8) and the lowest for T_8 (7.1) (Figure 14). The judges were not in an agreement with regard to any of the sensorial characters of the wines prepared with baker's yeast.

Table 6. Effect of treatments and selected pure strain on organoleptic qualities of wines

Treat-ments	Character (Mean score)						
	Colour and appearance	Flavour	Astringency	Sugar acid blend	Taste	Alcohol strength	Overall acceptability
T_1	8.1 (5.50)	8.1 (5.50)	7.0 (6.25)	7.6 (4.50)	7.9 (5.65)	7.0 (3.45)	7.8 (5.65)
T_2	7.9 (4.60)	7.2 (4.15)	6.4 (4.65)	7.9 (5.20)	7.9 (5.65)	7.9 (5.50)	7.9 (5.85)
T_3	7.3 (3.35)	7.3 (4.25)	6.2 (4.00)	7.5 (4.45)	7.3 (5.05)	7.0 (3.45)	7.3 (4.20)
T_4	7.8 (4.15)	7.3 (4.25)	6.9 (5.05)	7.5 (4.45)	7.7 (5.20)	7.2 (4.45)	7.4 (4.25)
T_5	7.2 (3.35)	7.1 (3.95)	6.1 (3.75)	7.3 (3.65)	7.2 (4.30)	7.5 (4.60)	7.2 (3.75)
T_6	8.3 (6.25)	7.8 (4.70)	6.5 (4.75)	7.5 (4.45)	7.7 (5.20)	7.7 (4.65)	7.5 (4.45)
T_7	7.6 (3.80)	7.2 (4.15)	6.1 (3.75)	7.4 (4.40)	7.1 (3.45)	7.5 (4.60)	7.3 (4.20)
T_8	8.0 (5.00)	7.4 (4.30)	6.4 (4.65)	7.7 (4.90)	7.3 (5.05)	7.8 (5.00)	7.9 (5.85)
Kendall's W value	24.1^{*}	5.8^{NS}	21.5^{*}	6.0^{NS}	16.2^{NS}	20.1^{*}	15.1^{NS}

Figure in parenthesis are mean rank score

* - significant at 5% NS - Not Significant

T_1 - Pulp + Sugar + PS/BY (control)
T_2 - Pulp + Sugar + PS/BY + pectinase
T_3 - Pulp + Sugar + PS/BY + KMS
T_4 - Pulp + Sugar + PS/BY + pectinase + KMS
T_5 - Pressure cooked pulp + Sugar + PS/BY
T_6 - Pressure cooked pulp + Sugar + PS/BY + pectinase
T_7 - Pressure cooked pulp + Sugar + PS/BY + KMS
T_8 - Pressure cooked pulp + Sugar + PS/BY + pectinase + KMS

Table 7. Effect of treatments and selected baker's yeast on organoleptic qualities of wines

Treat-ments	Character						
	Colour and appearance	Flavour	Astringe-ncy	Sugar acid blend	Taste	Alcohol strength	Overall acceptabil-ity
T_1	8.4 (4.95)	8.2 (5.35)	7.2 (5.25)	7.6 (5.05)	7.8 (5.45)	7.6 (4.55	7.6 (4.85)
T_2	7.9 (4.15)	7.7 (4.45)	6.3 (4.30)	7.4 (4.75)	7.6 (5.00)	7.8 (5.00)	7.8 (5.10)
T_3	7.9 (4.15)	7.4 (3.25)	6.4 (4.35)	7.3 (4.35)	7.7 (5.45)	7.6 (4.55)	7.5 (4.55)
T_4	8.0 (4.85)	7.6 (4.90)	6.5 (4.60)	7.7 (5.90)	7.8 (5.45)	7.5 (4.30)	7.7 (5.05)
T_5	8.0 (4.85)	7.6 (4.90)	6.7 (4.75)	7.3 (4.35)	7.5 (4.70)	8.0 (5.95)	7.6 (4.85)
T_6	7.9 (4.15)	7.8 (4.95)	6.5 (4.60)	7.4 (4.75)	7.4 (4.65)	7.6 (4.55)	7.5 (4.55)
T_7	7.8 (3.85)	7.0 (3.20)	6.4 (4.35)	7.2 (4.00)	7.1 (4.20)	7.4 (3.80)	7.2 (3.50)
T_8	8.0 (4.85)	6.9 (3.10)	6.4 (4.35)	7.0 (3.45)	6.7 (3.45)	7.3 (3.80)	7.1 (3.30)
Kendall's W value	6.6^{NS}	14.2^{NS}	4.4^{NS}	13.5^{NS}	18.3^{NS}	12.1^{NS}	11.8^{NS}

Figure in parenthesis are mean rank score

NS - Not Significant

T_1 - Pulp + Sugar + PS/BY (control)
T_2 - Pulp + Sugar + PS/BY + pectinase
T_3 - Pulp + Sugar + PS/BY + KMS
T_4 - Pulp + Sugar + PS/BY + pectinase + KMS
T_5 - Pressure cooked pulp + Sugar + PS/BY
T_6 - Pressure cooked pulp + Sugar + PS/BY + pectinase
T_7 - Pressure cooked pulp + Sugar + PS/BY + KMS
T_8 - Pressure cooked pulp + Sugar + PS/BY + pectinase + KMS

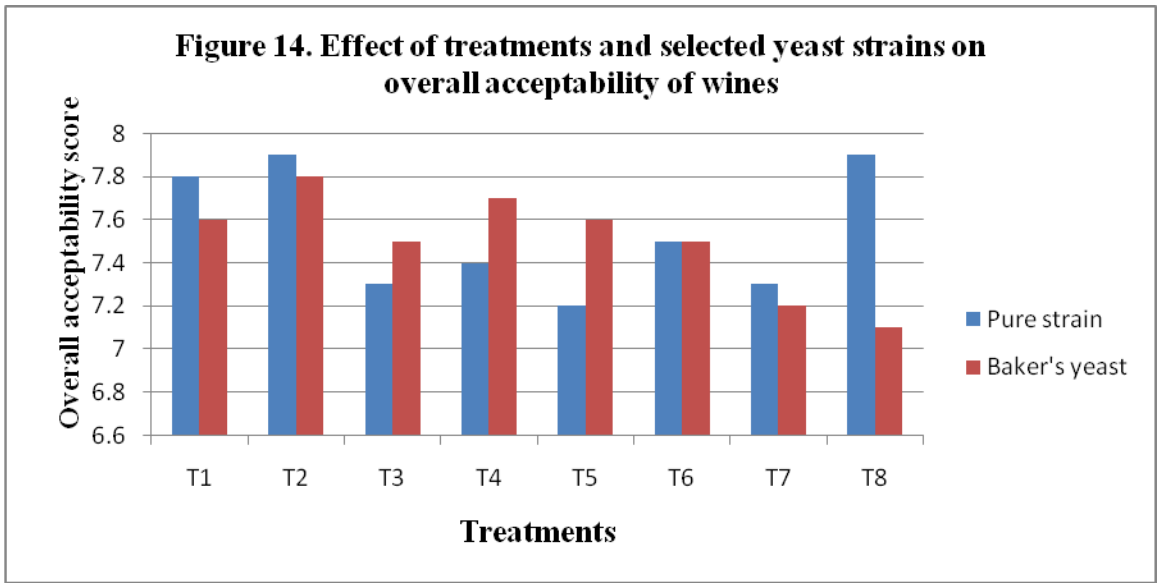


Figure 14. Effect of treatments and selected yeast strains on overall acceptability of wines
Overall acceptability score
8
7.8
7.6
7.4
7.2
7
6.8
6.6
T1
T2
T3
T4
T5
T6
T7
T8
Treatments
Pure strain
Baker's yeast

4. 2. 3. Selection of good quality wines for storage studies

Four wine treatments (two from pure strain and two from baker's yeast) were selected from the above sixteen treatments on the basis of the overall acceptability score and an acceptable level of alcohol content ranging from 8 to12 per cent required for a medium wine.

Among the eight treatments with the pure strain {MTCC 172, (10^6)}, T_2 and T_8 were selected which had an alcohol content of 9.4 and 8.16 per cent respectively and also showed maximum score for the acceptable level of alcohol strength (7.9 and 7.8 respectively). Overall acceptability score was also maximum in T_2 and T_8.

Among the eight treatments with baker's yeast (10^6), T_2 and T_4 were selected which had an alcohol content of 8.13 and 8.00 respectively and had the maximum overall acceptability score of 7.8 and 7.7 respectively.

4. 3. Quality of banana wines during storage

The selected wines were pasteurised and bottled in amber coloured bottles with cork caps and were stored for a period of three months in ambient temperature (Plate No. 6, 7, 8, 9, 10, 11, 12 and 13). Physico chemical attributes, organoleptic qualities and microbial studies were conducted in the wines before pasteurisation and after storage of three months.

4. 3. 1. Physico chemical attributes of banana wines in storage

The banana wines were analysed for different physico chemical attributes like clarity, alcohol content, pH, titrable acidity, TSS, reducing sugar, total sugar, pectin and tannin before and after storage. . Among the treatments, the difference in quality attributes during storage was interpreted by applying DMRT and is presented in the Tables 8 and 9. Comparison of physico chemical attributes of wines with each treatment initially and after storage was done by applying paired 't' test and is presented in Tables 10, 11, 12 and 13.

Plate 6. Banana wine (T_2PS) before storage

Plate 7. Banana wine (T_2PS) after storage

Plate 8. Banana wine (T_8PS) before storage

Plate 9. Banana wine (T_8PS) after storage

Plate 10. Banana wine (T_2BY) before storage

Plate 11. Banana wine (T_2BY) after storage

Plate 12. Banana wine (T_4BY) before storage

Plate 13. Banana wine (T_4BY) after storage

4. 3. 1. 1. Clarity

As revealed in Table 8, among treatments, initially the mean clarity of wines ranged from 75.83 to 83.93 per cent. Maximum clarity was for T_8PS and the least clarity in T_2PS which was significantly low when compared to other treatments.

After storage, the mean clarity of wines increased and varied from 80.42 to 87.42 per cent (Figure 15). The clarity of T_2PS was significantly low (80.42%) when compared to T_8PS (87.42%) and T_2BY (84.75%). T_4BY (82.83%) was on par with T_8PS and T_2BY.

As revealed in Table 10, there was a significant increase in the clarity of all the wines after storage.

4. 3. 1. 2. Alcohol content

As indicated in Table 8, there was an increase in the alcohol content of all the wines during storage. Among treatments, initially the alcohol content of banana wines varied from 8.00 to 9.40 per cent. The highest mean score was in T_2PS and the lowest in T_4BY. DMRT showed that alcohol content in T_2PS was significantly high when compared to other wines which showed no significant variation among themselves.

After storage, the mean score for alcohol content varied from 8.16 to 9.63 per cent. The highest alcohol was found in T_2PS which was significantly high when compared to other wines after storage (Figure 16).

As revealed in Table 10, there was no significant increase in the alcohol content of all the wines after storage.

4. 3. 1. 3. pH

Among treatments, as revealed in Table 8, initially the mean score of pH varied from 3.96 to 4.42. DMRT showed no significant difference in pH among the wines.

After storage, the pH of the wines showed a reduction and varied from 3.74 (T_2PS) to 4.20 (T_8PS) but there was no significant difference in the variation in pH of the wines (Figure 17).

As revealed in Table 11, there was no significant reduction in pH in all the wines after storage.

4. 3. 1. 4. Titrable acidity

Among treatments, as revealed in Table 8, initially the mean score for acidity of wines varied from 0.43 to 0.55 per cent. The treatments did not show any significant difference in acidity, except in T_2BY (0.43%) and T_2PS (0.55%). Acidity was significantly high in T_2PS but T_8PS (0.45%) and T_4BY (0.47%) were on par with T_2PS.

The final titrable acidity of banana wines varied from 0.70 to 0.79 per cent. The highest mean score was in T_2PS and the lowest mean score in T_8PS. As per DMRT, there was no significant difference among treatments with regard to acidity (Figure 18).

As revealed in Table 11, there was a significant increase in the titrable acidity of all the wines after storage.

4. 3. 1. 5. TSS

Among treatments, as revealed in Table 9, the initial TSS content varied from 13.60 to 14.23^0 Brix, the highest mean score was in T_4BY and the lowest in T_2PS. TSS was significantly high in T_4BY (14.23^0 Brix) and T_8PS (14.06^0 Brix) without significant variation. TSS in T_2PS (13.60^0 Brix) and T_2BY (13.70^0 Brix) were significantly low compared to T_4BY and T_8PS.

After storage, the TSS of banana wines showed a reduction and varied from 13.44 to 14.10^0 Brix (Figure 19). The highest mean score was in T_4BY and the lowest in T_2PS. T_8PS (13.93^0 Brix) and T_4BY (14.10^0 Brix) had no significant difference between themselves and showed significantly high TSS after storage, when compared to T_2PS (13.44^0 Brix) and T_2BY (13.56^0 Brix).

Table. 8. Effect of treatments and storage on physico chemical parameters of wines

Physico chemical parameters								
Treatments	**Clarity (%)**		**Alcohol content (%)**		**pH**		**Titrable acidity (%)**	
	Initial	**Final**	**Initial**	**Final**	**Initial**	**Final**	**Initial**	**Final**
T_2 PS	75.83[b]	80.42[b]	9.40 [a]	9.63 [a]	3.96 [a]	3.74 [a]	0.55 [a]	0.79 [a]
T_8 PS	83.93 [a]	87.42 [a]	8.16 [b]	8.27 [b]	4.42 [a]	4.20 [a]	0.45 [ab]	0.70 [a]
T_2 BY	80.58 [a]	84.75 [a]	8.13 [b]	8.31 [b]	4.01 [a]	3.79 [a]	0.43 [b]	0.75 [a]
T_4 BY	80.25 [a]	82.83 [ab]	8.00 [b]	8.16 [b]	4.33 [a]	4.06 [a]	0.47 [ab]	0.73 [a]

Figure with same superscripts form a homogenous subset

DMRT column wise comparison

Values are mean of 3 determinations

PS – Pure strain {MTCC 172 (10^6)} BY – Baker's yeast (10^6)

T_2PS – Pulp + sugar + PS + pectinase

T_8PS – Pressure cooked pulp + sugar + PS + pectinase + KMS

T_2BY - Pulp + sugar + BY + pectinase

T_4BY – Pulp + sugar + BY + pectinase + KMS

Table. 10. Effect of storage on clarity and alcohol content of wines

Physico chemical parameters						
Treatments	**Clarity (%)**			**Alcohol (%)**		
	Mean ± S. D		**t- value**	**Mean ± S. D**		**t- value**
	Initial	**Final**		**Initial**	**Final**	
T_2 PS	75.83 ± 1.19	80.42 ± 1.05	8.87 *	9.41 ± 0.18	9.63 ± 0.30	1.89 NS
T_8 PS	83.93 ± 2.98	87.42 ± 2.94	2.50 *	8.16 ± 0.21	8.27 ± 0.22	0.98 NS
T_2 BY	80.58 ± 2.00	84.75 ± 2.01	4.41 *	8.13 ± 0.20	8.30 ± 0.26	1.53 NS
T_4 BY	80.25 ± 3.00	82.83 ± 3.16	1.77 *	8.00 ± 0.27	8.16 ± 0.27	1.24 NS

Table 11. Effect of storage on pH and titrable acidity of wines

Physico chemical parameters						
Treatments	**pH**			**Titrable acidity (%)**		
	Mean ± S. D		**t- value**	**Mean ± S. D**		**t- value**
	Initial	**Final**		**Initial**	**Final**	
T_2 PS	3.96 ± 0.49	3.74 ± 0.39	1.06 NS	0.55 ± 0.10	0.79 ± 0.08	5.33 **
T_8 PS	4.42 ± 0.52	4.20 ± 0.39	0.99 NS	0.45 ± 0.07	0.70 ± 0.09	6.36 **
T_2 BY	4.01 ± 0.48	3.80 ± 0.28	1.17 NS	0.43 ± 0.06	0.75 ± 0.08	9.38 **
T_4 BY	4.33 ± 0.49	4.06 ± 0.35	1.13 NS	0.45 ± 0.06	0.73 ± 0.06	8.48 **

NS - Not Significant * - significant at 5% **- significant at 1%

PS – Pure strain {MTCC 172 (10^6)} BY – Baker's yeast (10^6)

T_2PS – Pulp + sugar + PS + pectinase

T_8PS – Pressure cooked pulp + sugar + PS + pectinase + KMS

T_2BY - Pulp + sugar + BY + pectinase

T_4BY – Pulp + sugar + BY + pectinase + KMS

Figure 15. Changes in the clarity of wines with storage

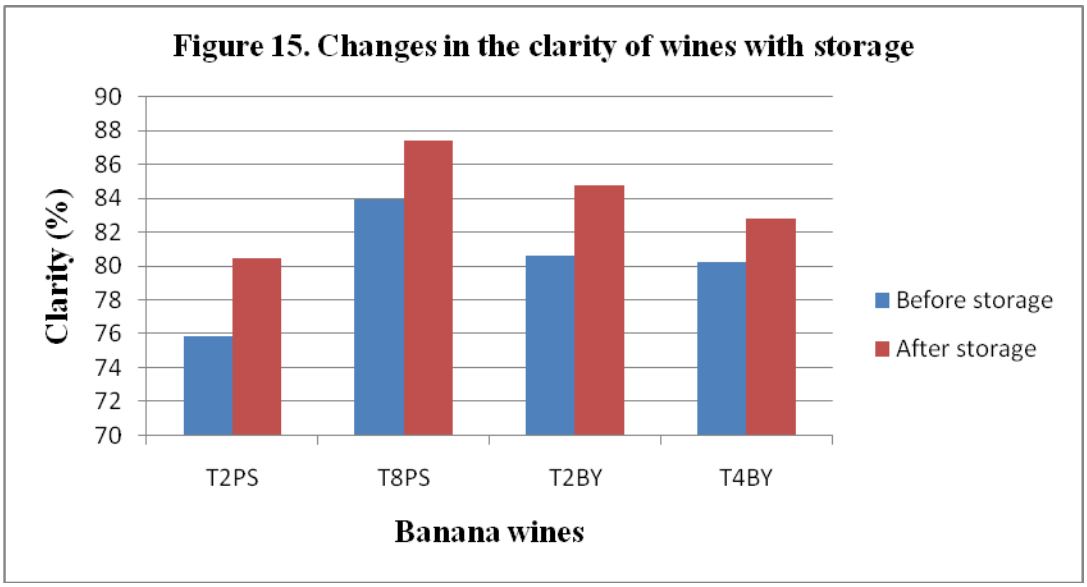


Figure 16. Changes in alcohol content of wines with storage

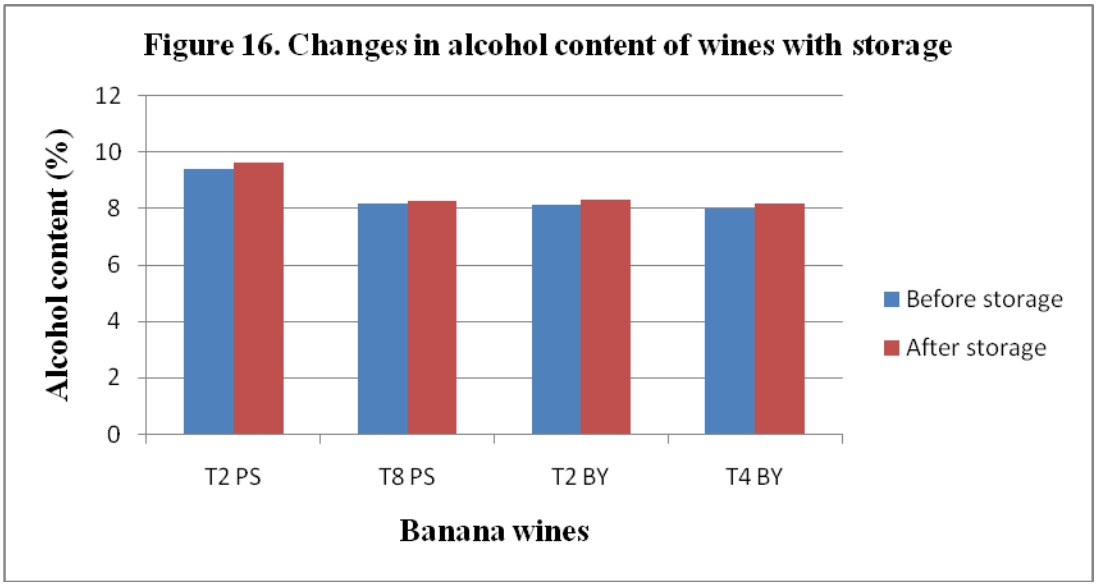


Figure 17. Changes in pH of wines with storage

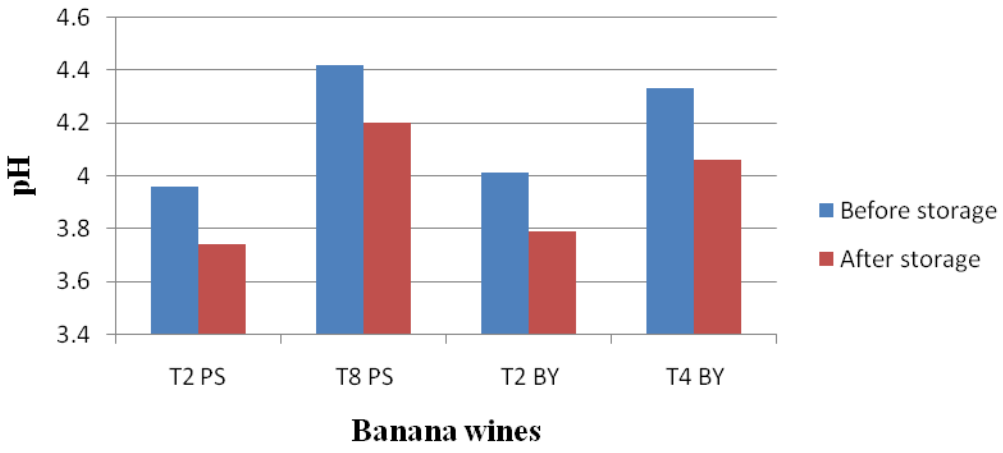
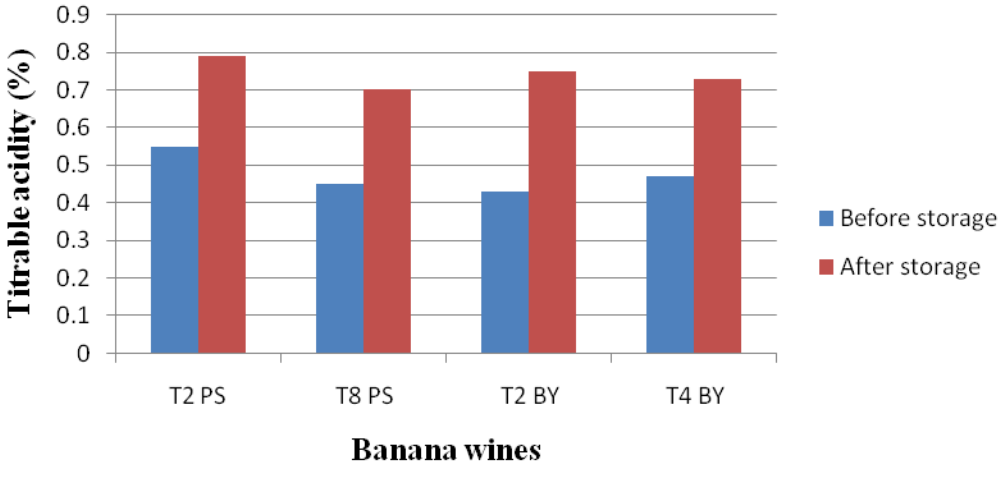


Figure 18. Changes in titrable acidity of wines with storage



As shown in Table 12, the reduction in the TSS of wines during storage was not significant.

4. 3. 1. 6. Reducing sugar

Among treatments, as revealed in Table 9, initially the reducing sugar varied from 2.89 to 3.15 per cent (Figure 20). Reducing sugar in T_2PS (2.89%) and T_2BY (2.96%) were significantly low compared to T_8PS (3.10%) and T_4BY (3.15%).

After storage, there was a reduction in reducing sugar of banana wines which varied from 2.36 to 2.91 per cent. Maximum reducing sugar was in T_4BY and the least in T_2PS. Reducing sugar was significantly low in T_2PS. T_2BY (2.52%) was on par with T_2PS.

As revealed in Table 12, the reduction in the reducing sugar content in all the wines during storage was significant.

4. 3. 1. 7. Total sugar

Among treatments, as given in Table 9, initially the total sugar varied from 11.05 to 12.96 per cent. The highest mean score was found in T_4BY and the lowest in T_2PS. DMRT showed that total sugar was significantly high in T_4BY (12.96%) and T_8PS (12.48%) when compared to T_2PS (11.05%) and T_2BY (11.44%).

After storage, there was reduction in total sugar content of wines which varied from 10.24 to 11.74 per cent (Figure 21). The highest mean score was found in T_4BY. T_8PS with a mean score of 11.13 per cent did not show significant difference with T_4BY. Total sugar in T_2PS (10.24%) and T_2BY (10.86%) were significantly low without showing difference between themselves. As revealed in Table 13, the reduction in total sugar content of all the wines during storage was not significant.

4. 3. 1. 8. Tannin and pectin

Among treatments, as revealed in Table 9, initially the mean score for tannin content varied from 0.007 to 0.010 mg/100ml (Figure 22). Maximum tannin was in

T_2BY and the lowest in T_8PS. Tannin content in T_2PS (0.008 mg/100ml) and T_4BY (0.009 mg/100ml) were on par with T_2BY.

After storage (Table 9), the tannin content of banana wines showed an increase which varied from 0.014 to 0.022 mg/100ml (Figure 22). Maximum tannin content was observed in T_2BY and the lowest tannin in T_8PS. Tannin content in T_2BY (0.022 mg/100ml) was significantly high. T_2PS (0.018 mg/100ml) and T_4BY (0.018 mg/100ml) showed no significant variation between themselves but, tannin content was significantly low compared to T_2BY.

As revealed in Table 13, the increase in tannin content of the wines after storage was found to be significant.

There was no pectin in the banana wines before and after storage, since the selected four wines were treated with the enzyme pectinase.

Table 9. Effect of treatments and storage on physico chemical parameters of wines

Physico chemical parameters								
Treatments	**TSS (^{0} Brix)**		**Reducing sugar (%)**		**Total sugar (%)**		**Tannin (mg/100ml)**	
	Initial	**Final**	**Initial**	**Final**	**Initial**	**Final**	**Initial**	**Final**
T_2 PS	13.60 ^{b}	13.44 ^{b}	2.89 ^{b}	2.36 ^{b}	11.05 ^{b}	10.24 ^{b}	0.008 ^{ab}	0.018 ^{b}
T_8 PS	14.06 ^{a}	13.93 ^{a}	3.10 ^{a}	2.64 ^{a}	12.48 ^{a}	11.13 ^{a}	0.007 ^{b}	0.014 ^{c}
T_2 BY	13.70 ^{b}	13.56 ^{b}	2.96 ^{b}	2.52 ^{ab}	11.44 ^{b}	10.86 ^{b}	0.010 ^{a}	0.022 ^{a}
T_4 BY	14.23 ^{a}	14.10 ^{a}	3.15 ^{a}	2.91 ^{a}	12.96 ^{a}	11.74 ^{a}	0.009 ^{ab}	0.018 ^{b}

Figure with same superscripts form a homogenous subset Values are mean of 3 determinations

DMRT column wise comparison PS- Pure strain BY- Baker's yeast

T_2PS – Pulp + sugar + PS + pectinase

T_8PS – Pressure cooked pulp + sugar + PS + pectinase + KMS

T_2BY - Pulp + sugar + BY + pectinase

T_4BY – Pulp + sugar + BY + pectinase + KMS

Table 12. Effect of storage on TSS and reducing sugar of wines

Physico chemical parameters						
Treatments	TSS (^{0}Brix)			Reducing sugar (%)		
	Mean ± S. D		t- value	Mean ± S. D		t- value
	Initial	Final		Initial	Final	
T_2 PS	13.60 ± 0.63	13.43 ± 0.40	0.67 ^{NS}	2.89 ± 0.03	2.36 ± 0.18	8.71 **
T_8 PS	14.06 ± 0.25	13.93 ± 0.19	1.27 ^{NS}	3.10 ± 0.29	2.64 ± 0.18	4.03 **
T_2 BY	13.70 ± 0.25	13.57 ± 0.45	0.77 ^{NS}	2.96 ± 0.57	2.52 ± 0.33	19.75 **
T_4 BY	14.23 ± 0.30	14.10 ± 0.22	1.07 ^{NS}	3.15 ± 0.11	2.91 ± 0.04	6.20 **

Table 13. Effect of storage on total sugar and tannin of wines

Physico chemical parameters						
Treatments	Total sugar (%)			Tannin (mg/100ml)		
	Mean ± S. D		t- value	Mean ± S. D		t- value
	Initial	Final		Initial	Final	
T_2 PS	11.05 ± 0.96	10.24 ± 1.29	1.51^{NS}	0.008 ± 0.002	0.017 ± 0.002	9.89 **
T_8 PS	12.47 ± 2.49	11.05 ± 0.96	1.60^{NS}	0.007 ± 0.002	0.014 ± 0.001	7.55 **
T_2 BY	11.43 ± 1.25	10.85 ± 1.51	0.89^{NS}	0.010 ± 0.001	0.022 ± 0.002	14.12 **
T_4 BY	12.96 ± 1.41	11.74 ± 1.10	1.67^{NS}	0.009 ± 0.001	0.018 ± 0.002	10.06 **

** - significant at 1% NS - Not Significant

PS- Pure strain BY- Baker's yeast

T_2PS – Pulp + sugar + PS + pectinase

T_8PS – Pressure cooked pulp + sugar + PS + pectinase + KMS

T_2BY - Pulp + sugar + BY + pectinase

T_4BY – Pulp + sugar + BY + pectinase + KMS

Figure 19. Changes in TSS of wines with storage

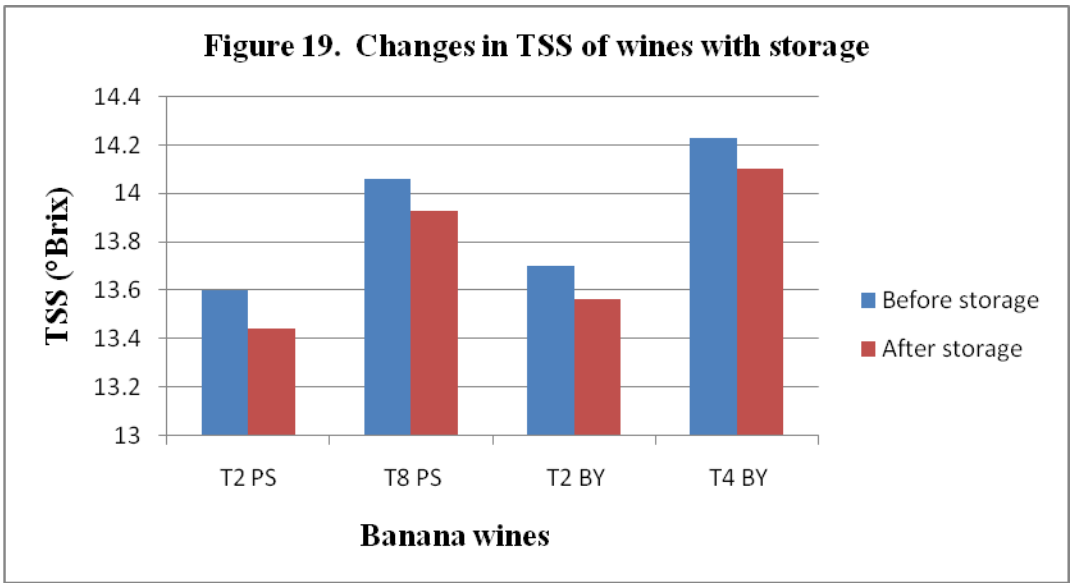


Figure 20. Changes in reducing sugar of wines with storage

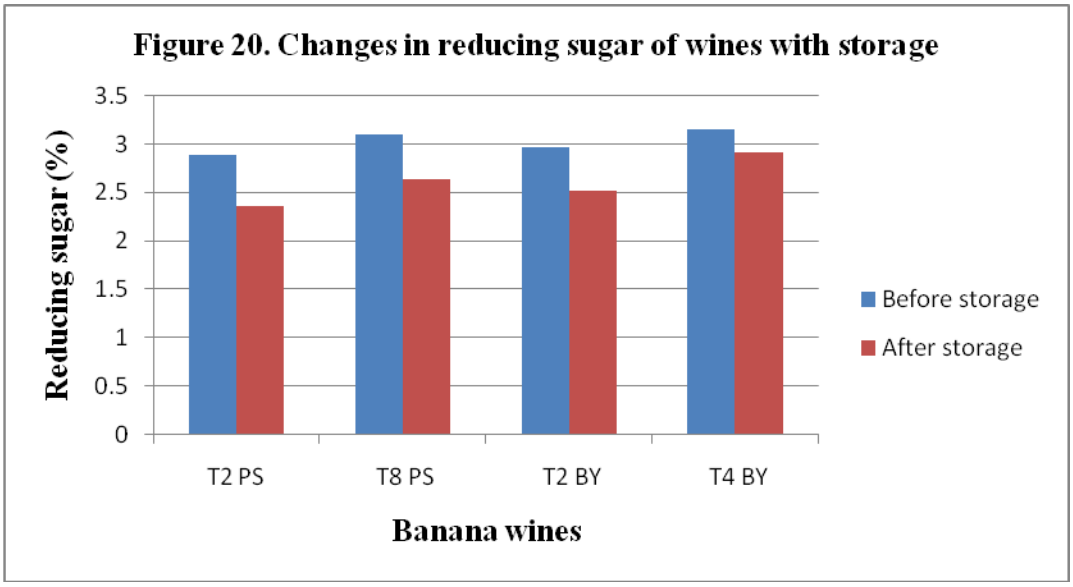


Figure 21. Changes in total sugar of wines with storage

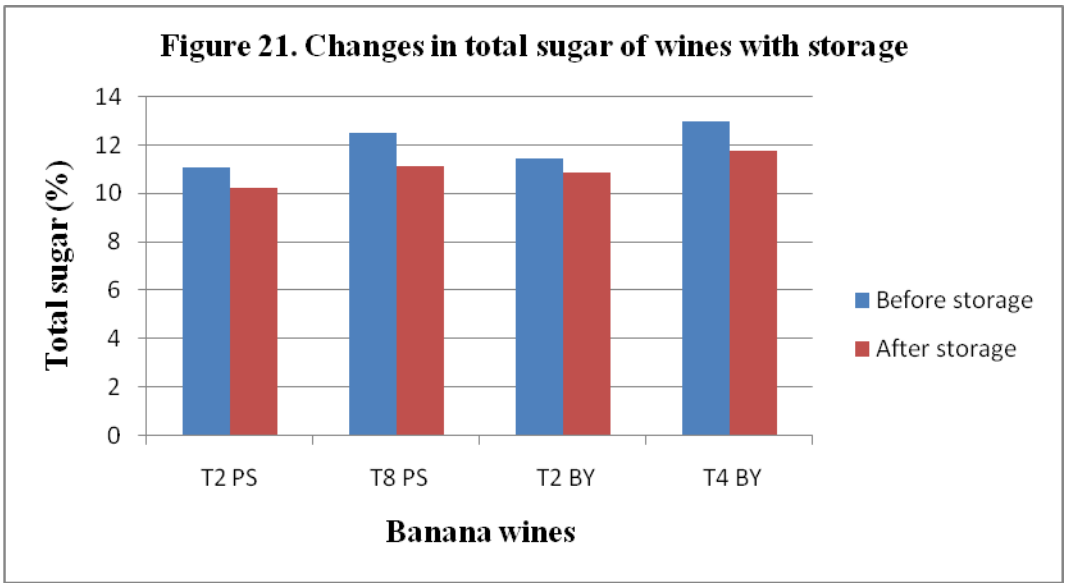
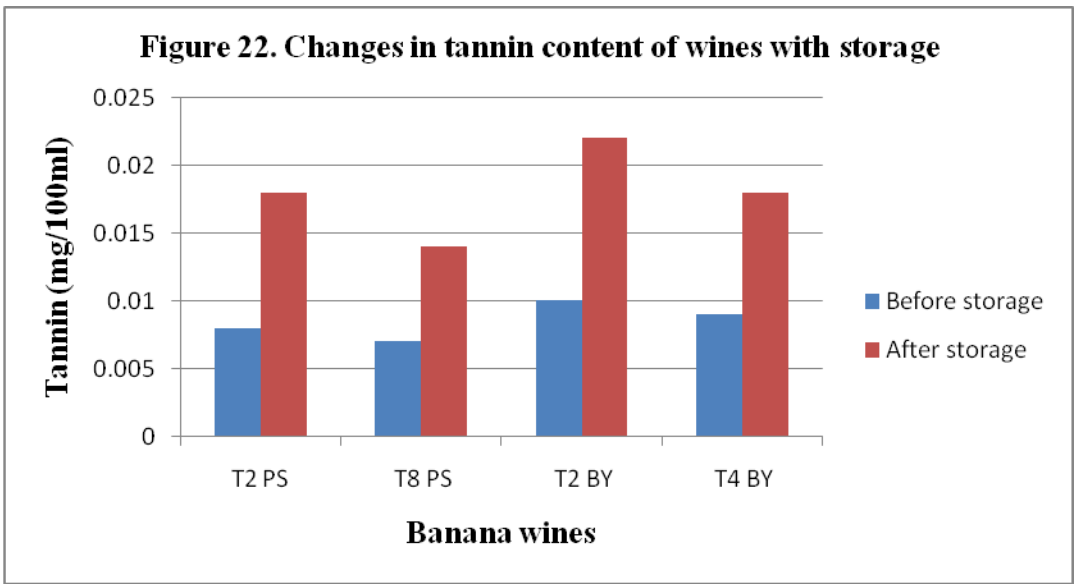


Figure 22. Changes in tannin content of wines with storage



4. 3. 2. Organoleptic qualities of banana wines in storage

The sensory evaluation of the wines were done initially and after storage and the results are presented in Table 14 (a), 14(b) and 15. Among the treatments, the quality attributes were interpreted by applying Kendall's coefficient of concordance and is presented in the Tables 14(a) and 14(b). Comparison of sensory attributes of each treatment initially and after storage was done by applying Wilcoxon signed rank test and is presented in Table 15.

Table 14(a) showed that, initially the mean score for colour and appearance of the wines varied from 7.9 to 8.0. Highest score was for T_8PS and T_4BY and the lowest for T_2PS and T_2BY. The panelists were not in an agreement with this quality of wines. After storage the mean score for colour and appearance varied from 7.3 to 8.1. Maximum score was for T_2BY and the lowest score for T_8PS. The panelists were in an agreement with the high mean rank score of 3.35 in T_2BY for colour and appearance.

As revealed in Table 15, there was no significant difference in colour and appearance of all the wines after storage.

Table 14(a) revealed that, among treatments, initially the mean score for flavour varied from 7.2 to 7.7. Maximum score was for T_2BY and the lowest score for T_2PS. After storage the mean score varied from 7.1 to 8.1, maximum being in T_2PS. The panelists were not in an agreement with the attribute flavour of wines initially and after storage. But as per Table 15, there was a significant increase in flavour score after storage in T_2PS (8.1)

Among treatments, initially {Table 14(a)}, the mean score for desirable level of astringency varied from 6.3 to 6.5 and the panelists were not in an agreement with this quality attribute. After storage, the mean score varied from 6.7 to 7.9, the maximum being in T_2PS. The high mean rank score of 3.35 in T_2PS indicated an agreement among panelists regarding the high acceptable level of astringency in T_2PS. As revealed in Table 15, there was a significant increase in the desirable level of astringency in T_2PS and T_2BY in storage.

Among treatments as revealed in Table 14 (b), the mean score for sugar acid blend initially varied from 7.4 to 7.9. Maximum score was for T_2PS and the lowest score for T_2BY. There was no agreement among the panelists with regard to sugar acid blend of wines initially. After storage, the mean score varied from 6.8 to 8.1, maximum in T_2PS and lowest in T_8PS. The panelists were in an agreement with the desirable level of sugar acid blend in wines after storage. Table 15 revealed that the increase in sugar acid blend of T_2PS and T_2BY were not significant, but the reduction in the desirable level of sugar acid blend in T_8PS and T_4BY were significant.

Among treatments {Table 14(b)}, initially the mean score for taste of the wines varied from 7.3 to 7.9. Maximum score for taste was for T_2PS and lowest in T_8PS. After storage the mean score for taste showed an increase which varied from 7.5 to 8.2. Maximum score was for T_2PS and lowest score for T_8PS. Initially the panelists were in an agreement with respect to this quality attribute in wines with the highest mean rank score in T_2PS (2.75). But after storage the taste panel was not in an agreement with regard to the taste of the wines. As revealed in Table 15, the increase in the taste score after storage was not significant in all the wines.

Among treatments, initially {Table 14 (b)} the acceptable level of alcohol strength in wines varied from 7.8 (T_8PS) to 8.0 (T_4BY). After storage the acceptable level of alcohol strength varied from 7.4 (T_8PS) to 8.0 (T_2PS). The judges were not in an agreement with this quality aspect in wines initially as well as finally after storage. As revealed in Table 15, there was no significant variation in the acceptable alcohol strength in wines during storage, but in T_4BY a significant reduction was observed.

Among treatments, initially the mean score for overall acceptability {Table 14(b)} varied from 7.7 to 7.9 (Figure 23). Maximum overall acceptability was for T_2PS and the lowest for T_4BY. After storage, the mean score varied from 7.4 to 8.1 {Table 14(b)} maximum being in T_2PS. But the panelists were not in an agreement with the rank scores for the overall acceptability of wines initially as well as finally after storage. Table 15 revealed no significant difference in the overall acceptability of wines after storage.

Table 14(a). Organoleptic qualities of wines in storage

Treat-ments	Character (Mean score)					
	Colour and appearance		Flavour		Astringency	
	Initial	Final	Initial	Final	Initial	Final
T_2 PS	7.9 (2.45)	7.5 (2.50)	7.2 (1.90)	8.1 (3.00)	6.4 (2.45)	7.9 (3.35)
T_8 PS	8.0 (2.75)	7.3 (1.60)	7.4 (2.90)	7.1 (1.90)	6.4 (2.45)	6.7 (1.95)
T_2 BY	7.9 (2.30)	8.1 (3.35)	7.7 (2.90)	7.9 (2.80)	6.3 (2.40)	7.2 (2.65)
T_4 BY	8.0 (2.50)	7.5 (2.55)	7.6 (2.70)	7.6 (2.30)	6.5 (2.60)	6.8 (2.05)
Kendall's W value	5.3^{NS}	42.5^{**}	25.5^{NS}	22.4^{NS}	4.3^{NS}	27.5^{*}

Figures in parenthesis are mean rank score

PS- Pure strain BY- Baker's yeast

* - 5% significance ** - 1% significance NS – Not Significance

T_2PS – Pulp + sugar + PS + pectinase

T_8PS – Pressure cooked pulp + sugar + PS + pectinase + KMS

T_2BY - Pulp + sugar + BY + pectinase

T_4BY – Pulp + sugar + BY + pectinase + KMS

Table 14(b). Organoleptic qualities of wines in storage

Treat-ments	Character (Mean score)							
	Sugar acid blend		Taste		Alcohol strength		Overall acceptability	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final
T_2 PS	7.9 (2.75)	8.1 (3.35)	7.9 (2.75)	8.2 (2.90)	7.9 (2.55)	8.0 (2.80)	7.9 (2.90)	8.1 (2.80)
T_8 PS	7.7 (2.50)	6.8 (1.80)	7.3 (2.05)	7.5 (1.95)	7.8 (2.40)	7.4 (2.05)	7.9 (2.55)	7.3 (2.15)
T_2 BY	7.4 (2.20)	7.6 (3.00)	7.6 (2.50)	8.2 (2.80)	7.8 (2.30)	7.7 (2.60)	7.8 (2.45)	7.8 (2.65)
T_4 BY	7.7 (2.55)	6.9 (1.85)	7.8 (2.70)	7.9 (2.35)	8.0 (2.75)	7.5 (2.55)	7.7 (2.10)	7.4 (2.40)
Kendall's W value	7.9^{NS}	46.5^{**}	27.1^{*}	21.7^{NS}	5.4^{NS}	7.3^{NS}	17.8^{NS}	13.6^{NS}

Figures in parenthesis are mean rank score

PS- Pure strain BY- Baker's yeast

* - 5% significance ** - 1% significance NS – Not Significance

T_2PS – Pulp + sugar + PS + pectinase

T_8PS – Pressure cooked pulp + sugar + PS + pectinase + KMS

T_2BY - Pulp + sugar + BY + pectinase

T_4BY – Pulp + sugar + BY + pectinase + KMS

Figure 23. Overall acceptability of banana wines in storage

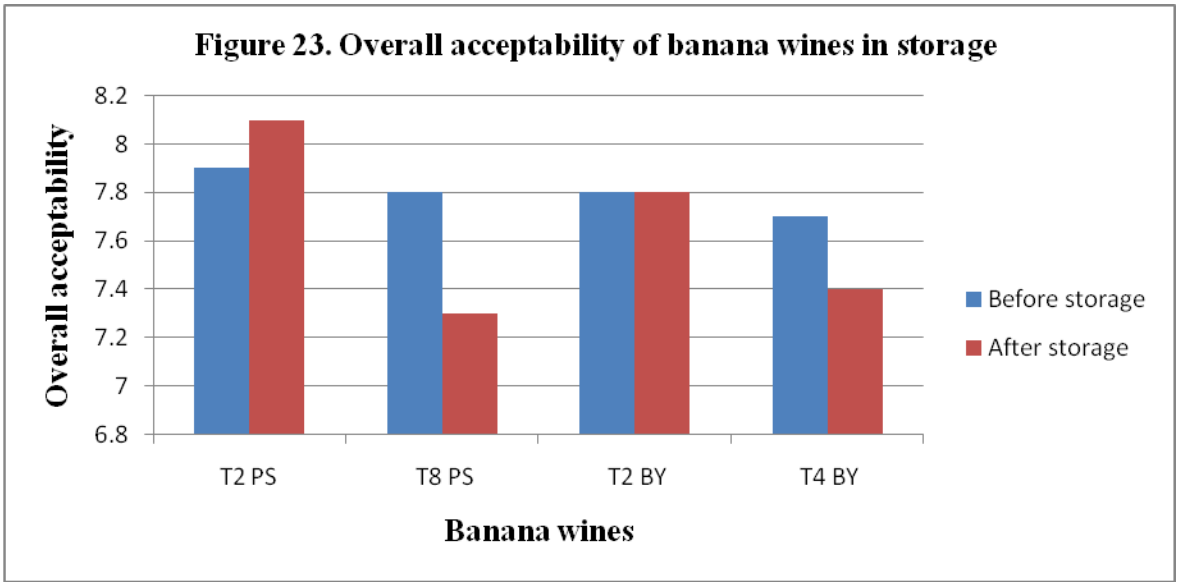


Table. 15. Effect of treatments and storage on the organoleptic qualities of banana wines

Treatments	Quality attributes						
	Colour and appear-ance	Flavour	Astring-ency	Sugar acid blend	Taste	Alcohol strength	Overall acceptability
T_2PS	1.63^{NS}	2.46*	2.75*	1.00^{NS}	1.51^{NS}	0.35^{NS}	1.00^{NS}
T_8PS	1.74^{NS}	1.08^{NS}	1.34^{NS}	2.53*	0.37^{NS}	1.34^{NS}	0.44^{NS}
T_2BY	0.64^{NS}	1.00^{NS}	1.99*	0.55^{NS}	1.00^{NS}	1.41^{NS}	0^{NS}
T_4BY	1.51^{NS}	0^{NS}	1.34^{NS}	1.94*	0.57^{NS}	2.23*	1.63^{NS}

Z statistic computed based on Wilcoxon signed rank test.

PS- Pure strain BY- Baker's yeast

T_2PS – Pulp + sugar + PS + pectinase

T_8PS – Pressure cooked pulp + sugar + PS + pectinase + KMS

T_2BY - Pulp + sugar + BY + pectinase

T_4BY – Pulp + sugar + BY + pectinase + KMS

4. 3. 3. Microbial count of wines before and after storage

The population of total microflora was assessed initially before pasteurisation and also after pasteurisation and three months of storage and is presented in Table 16.

4. 3. 3. 1. Microbial count of yeast in banana wine

As per Table 16, initially the yeast count ranged from $7x10^6$ cfu/ml to $9x10^6$ cfu/ml. The lowest count was in T_2BY, while the highest was in treatment T_4BY. The yeast count in T_2PS and T_8PS was found to be $8x10^6$ cfu/ml. There was no yeast in wines after storage.

4. 3. 3. 2. Microbial count of bacteria in banana wine

As per Table 16, the bacterial count was highest in T_2PS ($3x10^6$ cfu/ml) while

the lowest was in T_4BY ($1x10^6$ cfu/ml). A bacterial count of $2x10^6$ cfu/ml was observed in T_8PS and T_2BY. There was no bacteria in the wines after storage.

4. 3. 3. 3. Microbial count of fungi in banana wine

Fungal colony was observed (Table 16) only in T_2PS ($1x10^6$ cfu/ml) while no colonies were observed in other treatments.

The microbial study showed that fungi was absent in all the wines after storage.

Table 16. Microbial count of wines in storage

Treat-ments	Microbial population (cfu/ml)					
	Yeast ($x10^6$)		Bacteria ($x10^3$)		Fungi ($x10^3$)	
	Initial	Final	Initial	Final	Initial	Final
T_2 PS	8	0	3	0	1	0
T_8 PS	8	0	2	0	0	0
T_2 BY	7	0	2	0	0	0
T_4 BY	9	0	1	0	0	0

PS- Pure strain BY- Baker's yeast

T_2PS – Pulp + sugar + PS + pectinase

T_8PS – Pressure cooked pulp + sugar + PS + pectinase + KMS

T_2BY - Pulp + sugar + BY + pectinase

T_4BY – Pulp + sugar + BY + pectinase + KMS

4. 4. Cost of production of the most acceptable wine

Based on the highest overall acceptability score after the storage (8.1) and a medium alcohol content (9.63%), T_2PS (Pulp + sugar + MTCC 172 10^6 + enzyme) was selected from the four treatments (T_2PS, T_8PS, T_2BY and T_4BY) for calculating the cost of production of banana wine.

The approximate cost of production of the selected banana wine (T_2PS) is presented in Table 17.

As revealed from the Table, the cost of one bottle (750 ml) banana wine was Rs. 96/- whereas the cost of one bottle (750 ml) of grape wine was Rs. 150/-

Table 17. Cost of production of selected wine (T_2PS)

Ingredients	**Quantity**	**Approximate cost (Rs.)**
Banana*	724 (g)	12.00
Sugar	463 (g)	14.50
Pure strain	0.13 ml	1.00
Pectinase	0.28 g	36.00
Cost of sealing and labeling	1 bottle	2.00
Cost of bottle	1 bottle	7.00
Labour requirement	35 minutes	18.00
Other cost including fuel charge	1 bottle	5.00
Banana wine	**750 ml**	**96.00**
Grape wine	**750 ml**	**150.00**

***** Banana with peel

DISCUSSION

5. DISCUSSION

The discussion pertaining to the study is presented under the following headings

5. 1. Quality evaluation of banana wines prepared with pure strains and baker's yeast
5. 2. Effect of treatments on the quality of banana wines
5. 3. Quality changes in banana wines during storage

5. 1. Quality evaluation of banana wines prepared with pure strains and baker's yeast

Physico chemical parameters

Wine fermentation is either performed naturally without inoculation or by inoculating fruit juice with selected yeast. *Saccharomyces cerevisiae* is the most common species of yeast used as both baker's and brewer's yeast.

Different strains of this species have slightly different characteristics that make them uniquely suitable for different applications. Thus a strain with a higher than normal tolerance for ethanol would be of use in the fermentation process of alcoholic beverages, and a strain with a higher than normal tolerance for high concentration of sugar, might be used in the production of sweet baked goods.

The composition and quality of a wine is closely related to the yeast used. Hence one of the objectives of the present study was to standardise banana wines with pure strains of wine yeast and with baker's yeast. Because it is readily available and easy to culture, baker's yeast has long been used in wine making.

In the present study, three pure strains of *Saccharomyces* and the commercial baker's yeast were used each in two different dilutions (10^6 and 10^7) for fermentation of banana pulp. The results showed that most of the physico chemical parameters were significantly different depending on the yeast strain used. Wine yield with baker's yeast, were significantly high in both dilutions (68.36 and 67.76% respectively) when compared with the wine yield with pure strains. Among the pure strains of *Saccharomyces cerevisiae* used, maximum wine yield was for MTCC 172 in 10^6 dilution (59.53%) and 10^7 dilution was on par with 10^6 dilution. The pure strain MTCC 174 showed the least wine yield in 10^6 and 10^7 dilutions (50.17 and 50.75%

respectively). These results are in agreement with Erten and Campbell (2001), who observed that the use of carefully selected yeast strain can be considered as an important factor of wine yield in wine making process. But Carvalho (2001) found no significant difference in the wine yield with cashew apple juice fermented with three different pure strains of *Saccharomyces cerevisiae*. According to her, the wine yield with cashew apple juice varied from 83.89 to 97.5 per cent.

According to Vidrih and Hribar (1999), ethanol production capacity of yeast strains are of interest in the production of high quality wines. In the present study, among the wines with pure strains, MTCC 174 produced significantly high ethanol in banana wines in 10^7 dilution (9.87%). In 10^6 dilution also, this strain produced high alcohol in wine (9.07%). Among the other two pure strains, MTCC 172 showed no significant variation in alcohol production in both dilutions (8.33 and 8.57%) but the strain MTCC 180, showed high alcohol content in 10^6 dilution (8.80%) and in 10^7 dilution the alcohol production was significantly low (8.00%). Among wines with baker's yeast, there was no significant variation in alcohol content. Wine with baker's yeast in 10^7 dilution had the least alcohol content (7.13%) among all the wines.

The alcohol content in banana wines (*Palayankodan*) in the present study were found to be low when compared to an alcohol content of 9.96 to 11.25 per cent in wines prepared with *Musa species* (banana, cooking banana and plantain) using baker's yeast as inoculums by Onwuka and Awam (2001). A higher alcohol content of 10.6 per cent was reported in wines prepared from cashew apple juice using baker's yeast by Akinwale (1999). But ethanol concentration in mango wines were reported to be low ranging from 6.3 to 8.5 per cent using three yeast strains viz *Saccharomyces cerevisiae* CFTRI 101, palm wine isolate and baker's yeast by Reddy and Reddy (2009).

As the yeasts utilise sugar, which is converted to alcohol, there was a fall in TSS, which simultaneously resulted in a drop in pH and increased total acidity. Among the wines with both baker's yeast and pure strains, lowest TSS was in T_3 (11.93^0Brix) with a significantly high level of alcohol (9.07%). Maximum titrable acidity was observed in this treatment (0.92%) with a corresponding reduction in pH (3.61).

Among wines with baker's yeast, there was no significant variation in the TSS content but a significant variation in titrable acidity was observed. The titrable acidity observed in the present study was lower than the titrable acidity in *Musa* wines reported by Onwuka and Awam (2001). This may be due to the ability of the yeast strain used by the authors to utilise more sugars with the production of a higher alcohol content that ranged from 9.96 to 11.25 per cent in *Musa* wines. Whereas in our study, the alcohol content in banana wines ranged from 7.13 to 9.87 per cent. Earlier studies had reported that different strains of yeast will lead to different alcohol contents and different quantities of residual sugars in wines (Goreinsterin *et al.,* 1984, Obisanya *et al.,* 1987, Aderlye *et al.,* 1991).

Organoleptic qualities

Among the pure strains, a mean score of more than 8.00 was obtained by T_1 (MTCC 172, 10^6 dilution) for colour and appearance and flavour of the wines. The mean score for the desirable level of astringency varied from 6.6 to 7.4 maximum in T_5 (MTCC 180, 10^6 dilution). The panelists observed the optimum sugar acid blend in T_3 (MTCC 174, 10^6 dilution) with the highest score of 7.8. Highest score for taste (7.9) was for T_1 (MTCC 172, 10^6 dilution) and T_4 (MTCC 172, 10^7 dilution). Score for desirable alcohol strength was maximum (7.9) in T_4 (MTCC 174, 10^7 dilution). Overall acceptability score was high (7.8) in T_1 (MTCC 172, 10^6 dilution).

Among wines with baker's yeast, T_7 (10^6 dilution) showed the best score for colour and appearance (8.4), sugar acid blend (7.6), taste (7.8), acceptable alcohol strength (7.6) and for flavour (8.2) even superior to the score of T_1 but its overall acceptability score of 7.6 was next to that of T_1.

Synthesis of different types of alcohols during fermentation may influence the flavour of wines. Fermentation changed the aroma of fruit juice because of the production of yeast volatiles and the metabolism of original fruit volatiles. As reported by Vilanova *et al.* (2005) the levels of alcohols in wines produced from same variety of fruits will differ with yeast employed for the fermentation and the yeast cell plays a decisive role in the fermentation of higher alcohols which contribute to the flavour of the wine. Kunkee and Vilas (1994) had reported that the synthesis of acetic acid, iso-butanol and iso-amyl alcohol during fermentation which contribute to wine flavour, depends primarily on yeast strain.

The significant higher score for flavour for wine with baker's yeast (T_7) in the present study may be due to the strains in baker's yeast producing different alcohols. Fermentation studies with three yeast strains on ten mango cultivars by Reddy and Reddy (2009) also revealed that, the yeast strain *Saccharomyces cerevisiae* CFTRI 101, produced a good number of aroma components in mango wines.

With respect to the physico chemical parameters and overall acceptability, T_1 {MTCC 172 (10^6)} was selected from the three pure strains and the commercial baker's yeast (10^6 dilution) was selected for preparing banana wines.

5. 2. Effect of treatments on the quality of banana wines

Physico chemical parameters

The presence of pectin in wines can result in colloidal suspension which can make filtration and juice extraction more difficult. Banana is also rich in polyphenol oxidase enzyme which can cause discolouration of wines. Hence treatment with commercial pectinase enzyme, potassium metabisulphite and pressure cooking of banana pulp as a pretreatment were done to evaluate the quality aspects of wines.

There was a significant increase in wine yield in T_7 (70.43%) with pure strain when compared to the control. In T_7 banana pulp was pressure cooked and treated with KMS. Among various treatments, wine yield with baker's yeast also showed a significant increase. Maximum wine yield of 81.94 per cent was in the treatment T_4 (pulp + pectinase + KMS). A wide variation was observed in wine yield in different treatments with baker's yeast {Table 4(a)}.

Among the same treatments with baker's yeast and pure strain, there was no significant variation in wine yield in treatments T_5, T_6 and T_7. In all other treatments, wine yield was significantly high with baker's yeast when compared to wines with pure strain {Table 5 (a)}.

The wine yield was higher with the selected pure strain and baker's yeast in treatments with pectinase and KMS. Rombouts and Pilnik (1978) had recommended the use of pectic and cellulolytic enzymes in wine industry to aid in juice clarification and increased yield. Viquez *et al.* (1981) also used pectinolytic enzymes to increase the wine yield from banana pulp. According to Cheirsilp and Umsakul (2008), banana pulp should be treated with pectinase and α amylase to hydrolyse the pectin and starch

to produce more wine. In the present study, higher wine yield in enzyme treated substrate may be due to the hydrolysis of complex carbohydrates like pectin in banana, which will decrease the viscosity and resulted in increased wine production. Wine yield was more than 70 per cent in enzyme treated samples *viz* T_2 (78.28% - pulp + sugar + BY + enzyme), T_4 (81.94%- Pulp + BY+ enzyme + KMS) and T_6 (71.36% - Pressure cooked pulp + BY + enzyme) using baker's yeast and in T_7 (70.43% - Pressure cooked pulp + PS + KMS) using pure strain for fermentation.

Clarity of the wines (pure strain and baker's yeast) showed an improvement in most of the treatments when compared to the control (T_1). Here also maximum clarity of wines were observed in enzyme and KMS treated samples (T_2, T_4, T_6 and T_8) using both pure strain and baker's yeast. Among these two types of yeasts, wines with baker's yeast showed a higher clarity for wines with a maximum of 86.08 per cent in T_6 (Pressure cooked pulp + enzyme) followed by T_8 (84.75% - Pressure cooked pulp + enzyme + KMS). But the variations observed in the clarity of wines with pure strain and baker's yeast in each treatment was not significant {Table 5(a)}.

Generally wines become clearer towards the end of fermentation as reflected by a higher percentage light transmittance. One of the major causes of haze formation in wine is attributed to the presence of cloud forming pectic substances particularly pectin. These substances are located in the cell walls and are liberated when the fruit is pulped. Bramwell (1998) reported that banana pulp contained 0.30 per cent pectin as calcium pectate which may have accounted for differences in clarity of the wines prepared. Cheirsilp and Umsakul (2000) also found that the clarity of the enzyme treated banana wines were four fold higher than that of the non enzyme treated banana wine.

In the present study maximum clarity transmittance per cent value of 86.08 was observed in T_6 with baker's yeast as compared to a value of 54.83 per cent for the control (T_1). However Brathwate and Badrie (2001) reported a transmittance per cent value of 99.50 for enzyme treated banana wines.

A significant variation was observed in the alcohol content of wines with different treatments. Among pure strain wines, treatments T_6 (10.26%), followed by T_2 (9.40%) showed maximum alcohol content. In both these treatments the substrates were treated with the enzyme. In wines with baker's yeast, the treatment T_5 showed

the maximum alcohol content of 10.16 per cent where the substrate was not treated with enzyme. However enzyme treated T_6 showed an alcohol content of 9.73 per cent without significant variation from T_5. But there was no significant variation with respect to the alcohol content of wines in each treatment with pure strain and baker's yeast {Table 5 (b)}.

The alcohol content of wines produced by different treatments in the present study is in line with the studies conducted by Bhajipale *et al.* (1998) who observed that the alcohol content of most of the fruit wines were below 12 per cent. Studies conducted by Carvalho (2001) also reported a maximum alcohol content of 10.95 per cent in wines prepared with differently treated cashew apple juice. But Joshi *et al.* (2000) reported an alcohol content of 12-13 per cent in enzyme treated pine apple wine. Brathwate and Badrie (2001) also found that addition of enzyme pectinase improved the alcohol content of banana wines. Reddy and Reddy (2009) revealed that pectinase treatment significantly increased the alcohol production from mango pulp using three different yeast strains. The increase in alcohol content may be due to must clarity and increased sugar concentration in pectinase treated samples. Bosso (1993) has also observed higher levels of alcohol in fermented grape must pretreated with pectolytic enzymes.

The variables related to fermentation vigour were alcohol content and sugar remaining after fermentation. In this study there was no significant variation in the sugar consumption rates among the pure strain yeast used for producing wines under different treatments Table 4 (b). In wines with baker's yeast, TSS showed a significant variation among treatments, but the difference in TSS content of wines with pure strain and baker's yeast in each treatment was not significant {Table 5 (a)} except in T_8 where the pure strain wine showed significantly high TSS. However, no significant difference was observed in the production rate of ethanol in each treatment with pure strain and baker's yeast {Table 5 (b)}.

In the present study, the TSS content of the banana must was adjusted to 20^0 Brix by ameliorating with sugar in all the treatments of wine production using pure strain and baker's yeast. Using pure strain, T_6 (Pressure cooked pulp + enzyme) showed the maximum reduction in TSS (13.43^0 Brix) with a maximum alcohol content of 10.26 per cent. This was followed by T_2 (pulp + enzyme) with a TSS of

13.60^{0}Brix after fermentation and an alcohol content of 9.40 per cent. In all the treatments with baker's yeast also, the changes in alcohol content corroborated with the decrease in TSS as described earlier. Highest reduction in TSS was observed in T_6 (Pressure cooked pulp + enzyme) with 11.73^{0}Brix followed by T_5 (Pressure cooked pulp) with 12.86^{0}Brix, which had an alcohol content of 9.73 and 10.16 per cent respectively. The TSS content had been reported to bear an inverse relationship with the alcohol of wine (Kotecha *et al.*, 1995). The lowest TSS observed was 11.73^{0}Brix in enzyme treated banana wine (T_6) which was found to be slightly higher than the TSS observed in enzyme treated banana wines (10.20^{0}Brix) by Kotecha *et al*. (1994). But Cheirsilp and Umsakul (2008) reported that the concentration of TSS and alcohol in enzyme treated banana wines and control have no significant difference.

Brathwaite and Badrie (2001) in their study with banana wines found that there was a greater utilization of TSS in wines treated with enzymes and with sodium metabisulphite. TSS was found to be 7.0^{0}Brix in enzyme treated banana wine as against 9.5^{0}Brix in wine with banana alone (control). In the present study among different treatments with pure strain, least utilization of TSS was observed in T_8 (14.60^{0}Brix) and with baker's yeast it was in T_4 (14.23^{0}Brix), both are treatments with enzyme and KMS. Alcohol content in these treatments was also found to be low (8.16 and 8.00% respectively). The residual sulphur dioxide in the KMS treated pulp might have inactivated the yeast resulting in incomplete fermentation with high TSS after fermentation.

In different treatments of wines produced by pure strain, the treatment with maximum sugar utilization (T_6) showed the maximum titrable acidity of 0.55 per cent (expressed as per cent of malic acid) with a corresponding low pH (3.95). This is the treatment with pressure cooked banana substrate treated with enzyme. T_2 (pulp + enzyme) with a TSS of 13.60°Brix also had the same titrable acidity with a low pH of 3.96. In treatments with baker's yeast also T_6 and T_5 (enzyme treated banana wine) with more sugar utilization showed a high titrable acidity of 0.92 and 0.94 per cent respectively. This has resulted in a low pH in these wines (3.64 and 3.55 respectively). Kotecha *et al*. (1994) observed a titrable acidity of 0.88 per cent in enzyme treated banana wine. Jackson and Badrie (2002) reported that the addition of enzyme did not show much difference in pH and titrable acidity in banana wine.

According to Simon and Badrie (2002) citric acid has been reported to be the major acid in plantain.

Type of yeast showed significant difference in the pH of the wines produced by the same treatments {Table 5 (b)} in T_3, T_5, T_6 and T_8. In T_3 (pulp + KMS), T_5 (pressure cooked pulp), T_6 (Pressure cooked pulp and enzyme treated) and T_8 (Pulp pressure cooked and treated with enzyme and KMS), pH of the wines were significantly low in wines with baker's yeast. Titrable acidity had no significant difference in the wines produced by the same treatment except in T_1, T_5 and T_6. In T_1 (control), T_5 (Pressure cooked pulp) and T_6 (pulp pressure cooked and enzyme treated) titrable acidity of the wines were significantly high with baker's yeast {Table 5(c)}.

Organoleptic qualities

Quality is a composite response to the sensory properties of wine based on assessor's expectations and hence an individual response is based on preferences and experiences (Noble *et at.,* 1984). Sensory qualities of wines depend on the type of fruit, yeast strain and must environment.

Effect of various treatments of banana pulp for wine production with the pure strain showed a maximum score of 8.3 for colour and appearance in T_6. All the wines showed a good yellow colour. A mean score of 8 and above was observed in T_6 (8.3), T_1 (8.1) and T_8 (8.0) which indicated "like very much" in the hedonic scale by the panelists. T_6 was the pressure cooked substrate treated with enzyme, T_8 with pressure cooked substrate treated with enzyme and KMS and T_1 the control. All other treatments showed a mean score of more than 7.2 for colour and appearance i.e. "like moderately to like very much". A high score of 8.3 for colour and appearance in T_6 may be due to the pressure cooking of banana pulp which might have destroyed the polyphenol oxidase enzyme in banana. Brathwaite and Badrie (2001) isolated a phenol oxidase enzyme from banana pulp which can catalyse the oxidation of a variety of diphenolic substances. Dopamine was reported to be the most reactive substrate for browning in banana pulp (Palmer, 1971). High clarity of wine (82.75 %) in T_6 may also be a factor contributing to the high score for colour and appearance.

Effect of various treatments on the mean score for colour and appearance of wines with baker's yeast varied from 7.8 to 8.4. Here the maximum score was for the control (T_1).

Generally wine yeasts are many strains of *Saccharomyces*, which not only can carry out complete fermentation of the fruit juice but also provide the fermented product with pleasant flavours. Many volatile compounds are responsible for the flavour (taste and aroma) of the wine. However, a quality product should always have these volatiles at acceptable levels. Among different treatments with pure strain and baker's yeast, maximum flavour score was for the control T_1 (8.1 and 8.2 respectively). Wines with pure strain showed a better flavour score in pressure cooked pulp treated with enzymes in T_6 (7.8) and in T_8 (7.4) with pressure cooked pulp treated with enzyme and KMS. With baker's yeast also T_6 (pressure cooked pulp treated with enzyme) and T_2 (pulp + enzyme) showed a slightly better flavour score of 7.8 and 7.7 respectively. Brathwaite and Badrie (2001) also observed highest aroma score for banana wines without any treatments. Pilnik *et al.* (1975) and Mchellen *et al.* (1985) reported a greater tissue break down, releasing more components, which could contribute to soluble solids in pectinase treated juices from apples, apricots and carrots which may have contributed to lower taste and aroma scores assigned to wines with enzyme. In the present study the mean flavour score for all the treatments with pure strain were above 7.1 (like moderately to like very much). But in treatments with baker's yeast T_8 (pressure cooked pulp with enzyme and KMS) showed the least flavour score of 6.9 (like slightly to like moderately)

A vast number of volatile compounds are also formed and modulated by yeast during alcoholic fermentation that significantly influence the flavour and overall quality of the wines (King *et al.,* 2008). The choice of the yeast strain used by the wine maker is mainly motivated by the potential impact of that strain on the wine characteristics (Sablayrolles, 2009). However, as pointed out by Swiegers and Pretorius (2005) not all *Saccharomyces* strains have the same capacity to produce these volatile compounds from differently treated musts.

The presence of tannins in plantain tissues are responsible for astringency (Seymour, 1993). Tannins interact with the salivary proteins and glycoproteins resulting in astringent taste (Haslan, 1981). In the present study all the wines with

different treatments both with pure strain and baker's yeast had an acceptable level of astringency as indicated by a mean score of more than 6.1 (like slightly to like moderately) except in T_1 (control) which had a mean score of more than 7.0 (like moderately to like very much).

Sugar acid blend of the wines contribute to the taste of the wine. Usually citric acid and malic acid tend to predominate in banana pulp. Maximum score (7.9) for acceptable sugar acid blend was for T_2 (pulp treated with enzyme) in pure strain wines. This may be because this treatment had the highest titrable acidity of 0.55 per cent and a TSS content of 13.60°Brix. Hence this treatment had the highest taste score also (7.9). Maximum alcohol content was in T_6 (10.26%) but the score for sugar acid blend was 7.5 with a taste score of 7.7. However a medium alcohol content of 9.40 per cent was found to be the most acceptable alcohol strength in T_2 (7.9). Regarding taste of wines with different treatments using pure strain, all the treatments had a mean score of more than 7.0 (like moderately to like very much). Maximum score for taste (7.9) was for T_1 and T_2. Mean score for acceptable alcohol strength was highest (7.9) in T_2 (pulp + enzyme). Mean score for overall acceptability of wines with pure strain varied from 7.2 to 7.9, maximum being in T_2 and T_8.

Among wines with baker's yeast, maximum acceptable sugar acid blend was in T_4 (7.7) with a TSS of 14.23°Brix and 0.47 per cent titrable acidity. Taste score was highest in T_1 (control) and also in T_4 (7.8). However mean score for overall acceptability was maximum in T_2 (7.8) followed by T_4 (7.7). The overall acceptability of wines with baker's yeast showed a mean score of more than 7.0 (like moderately to like very much).

Akubor *et al.* (2003) also found no significant difference in the sensory qualities of banana wines with respect to flavour, taste and overall acceptability, produced by different processing methods of banana pulp. But slightly less sensory qualities were found for the treated wines with enzymes (Ough and Bery, 1974).

Generally it is difficult to recommend specific optimum quality parameters for different wines. This is because the ideal characteristics of wine are very much dependent on the style and preference of the particular wine consumer. Ethanol is the main product of alcoholic fermentation and other byproducts of fermentation such as organic acids and esters should occur in acceptable amounts in wines. Among

treatments with MTCC 172, T_2 (pulp + sugar + PS + enzyme) and T_8 (pressure cooked pulp + sugar + PS + enzyme + KMS) were selected with maximum overall acceptability and also showed the maximum score for the acceptable level of alcohol strength (mean score of 7.9 and 7.8 respectively) as judged by the panelists, for storage studies. Among treatments with baker's yeast, the selected treatments were T_2 (pulp + sugar + BY + enzyme) and T_4 (pulp + sugar + BY + enzyme + KMS) based on the overall acceptability scores. All the four selected wines were found to be treated with pectinase (0.3%).

5. 3. Quality changes in banana wines during storage

Physico chemical parameters

Wine with more than 15 per cent alcohol generally does not get spoiled. But those with lesser quantity of alcohol are liable for spoilage. To preserve low alcoholic wines, pasteurisation or use of chemicals are normally done (Joshi, 1997). In the present study the selected wines were pasteurized before storage.

In the selected two treatments with pure strain and baker's yeast, there was a significant increase in the clarity of wines (Table 10) after storage. Initially clarity of T_2PS was significantly low (75.83%) when compared to the other wines (Table 8). After storage even though there was a significant increase in the clarity of all the wines, T_2PS showed significantly low wine clarity (80.42%) when compared to other wines after storage. Pure strain wine T_8PS (Pressure cooked pulp with enzyme and KMS) showed maximum clarity (87.42 %) after storage (Table 8). Akinwale (1999) also observed that during maturation of cashew apple wines more deposits settled from the wine and became clearer.

Initially the alcohol content of wines ranged from 8 to 9.4 per cent which increased to 8.16 to 9.63 per cent (Table 8) after storage. However the increase in alcohol content during storage in all the treatments was not significant (Table 10).

During storage of wines there was a slight reduction in the TSS of all wines with a corresponding increase in titrable acidity and a reduction in pH (Table 9 and 8), but the variations observed were not significant except in titrable acidity (Table 11 and 12). These results are in line with the results of Akinwale (1999) who also reported that in cashew apple wine, after six months of storage, there was an increase

in acidity and a slight reduction in pH. Significant increase in titrable acidity during storage can be attributed to the fact that the common acids in banana such as malic acid, citric and succinic acids are weak acids which produce few ions per mole of compound in the wine during ionization process. So this will not cause a significant reduction in the pH of banana wines during storage (Kyamuhangire *et al.,* 2002). In acceptable levels, these acids enhance the flavour of the wines and increase the palatability of the products. In this study also T_2PS with maximum titrable acidity after storage (0.79%) showed a significantly higher flavour score (7.9) and a high score for overall acceptability (8.1).

A decrease in total sugar and reducing sugar were observed in wines during storage. Initially the total sugar which varied from 11.05 to 12.96 per cent decreased to 10.24 to 11.74 after three months of storage, but the reduction was not significant (Table 13). However, reducing sugar showed a significant reduction during storage (Table 12). Initial reducing sugar which ranged from 2.89 to 3.15 per cent was reduced to a value of 2.36 to 2.91 per cent after storage (Table 9).

Gautam and Chundawat (1998) reported a total sugar content ranging from 2.47 to 2.60 per cent in sapota wine and Bhajipale *et al.* (1998) reported a total sugar content of 3.23 to 3.64 per cent in karonda wine. But this was not in agreement with the finding of the present study where the total sugar content of banana wines ranged from 10.24 to 11.74 per cent after storage, probably due to variation in the fermentation process by the wine yeast strain and other treatment variations.

The present finding suggests that the selected treatments with pure strain and baker's yeast resulted in banana wines which can be grouped as 'sweet wines' with an alcohol content ranging from 8.16 to 9.63 per cent and a total sugar content of more than 10 per cent after storage.

Factors affecting oxidative browning of white wines are the contents of total phenolics, catechins and procyanidins. Banana and plantain are rich in polyphenoloxidase enzyme which can oxidize a variety of phenolic compounds in the pulp affecting the colour of the wines. Compounds like tannins, norepinephrine, 5 hydroxytryptamine and dopamine are present in plantains and bananas (Foy and Paratt, 1960). In the present study, initially the tannin content of the selected wines varied from 0.007 to 0.01 mg/100ml which showed an increase to 0.014 to 0.022

mg/100ml after storage (Table 9). Tannin content was comparatively low in T_8PS (pressure cooked pulp + enzyme + KMS). Pressure cooking of the substrate and treatment with KMS which might have inactivated the polyphenolase enzyme. Even though there was a significant increase in the tannin content of banana wines after storage (Table 13) the total tannin content itself was comparatively low. But in acceptable level this might have contributed to the desirable level of astringency in the wines.

Organoleptic qualities

Quality refers to the 'degree to which a set of inherent characteristics fulfils requirements' where the requirements may differ from one person to other. Hence the sensorial attributes of wines that are most appreciated, will vary according to different consumers.

In the present study, the sensory qualities of the wines stored revealed that, there was no significant variation in the taste and overall acceptability of wines with storage (Table 15). Mean score for colour and appearance was maximum in T_2BY (8.1) when compared to other treatments after storage {Table 14 (a)}, but there was no significant variation in this attribute when compared to the initial mean score for each treatment (Table 15). An enhancement in wine flavour was observed in T_2PS and T_2BY after storage, and flavour was significantly high in T_2PS (Table 15). This increase in flavour may be due to the formation of a vast number of volatile compounds in wines during storage (King *et al.*, 2008). Here the treatments were same but the difference was in the yeast strain. T_2PS was the wine with the selected pure strain MTCC 172. This shows the importance of the choice of yeast strain in wine making as evidenced by the potential impact of this strain on the wine characteristics especially flavour. As pointed out by Sablayrolles (2009), not all *Saccharomyces* strains have the same capacity to reveal these flavour components in banana wines. Reddy and Reddy (2009) also reported that the formation and concentration of the volatile compounds contributing to the flavour of mango wines during storage was dependent on the mango cultivar and *S. cerevisiae* strain used.

Desirable astringent taste revealed by a higher mean score was observed in all the wines after storage {Table 14 (a)}. Significant increase in acceptability with regards to astringency (Table 15) was observed in T_2PS with a maximum score of 7.9

followed by T_2BY (7.2) both indicating a level from "like very much" to "like extremely" in the hedonic scale.

Mean score for taste was also maximum for T_2PS and T_2BY (8.2) after storage (Table 14 (b)}. The high score for acceptable sugar acid blend (8.1), most acceptable level of astringency (7.9), maximum score for flavour (8.1), least TSS (13.44°Brix) least total sugar (10.24%), least reducing sugar (2.35%) with a maximum alcohol content of 9.63 per cent in T_2PS after storage might have contributed to this high taste score in T_2PS (pulp + MTCC 172, 10^6 + enzyme) after storage. However the variations observed in the taste of wines during storage were not significant (Table 15).

Overall acceptability of T_2PS showed the maximum score (8.1) after storage (like very much to like extremely) {Table 14 (b)}. T_2BY (same treatment with baker's yeast) showed no difference in the mean score after storage (7.8) where as T_8PS and T_4BY showed a lesser score for overall acceptability after storage. However the variations in overall acceptability observed were not significant indicating between "like moderately to like very much". T_2PS is the treatment with pure strain using banana pulp and enzyme. Wimalsiri *et al.* (1971) had also observed that during ageing and subsequent maturing of wines in bottles, many reactions including oxidation occur with the formation of traces of esters and aldehydes, which together with tannin and acids already present, enhance the taste, aroma and overall acceptability of wines. The results of the sensory evaluation of the aged wine with cashew apple compared with the young wine conducted by Akimwale (1999) also revealed that aged wine was preferred and more acceptable in terms of colour, taste , flavour and overall acceptability . Sensory evaluation results of Akubor *et al.* (2003) showed that there were no significant difference in flavour, taste, clarity and overall acceptability between banana wine and a reference wine after storage. The banana wine was generally accepted.

Microbial studies

The wine making process is a complex ecological niche where the biochemistry and interaction of yeasts, bacteria, fungi and the viruses play a pivotal role in the quality of the product. The microbial spoilage ends up altering the quality and hygienic status of wine. This may render the wine unacceptable since the spoilage

can include bitterness and off flavours as well as problems like turbidity, viscosity sediment and film formation.

In the study, the yeast count of the wines varied from 7 to 9 cfu/ml initially before storage but no yeast was detected after storage. Similarly a bacterial population of 1 to 3 cfu/ml was observed initially but no bacterial population after storage. A fungal count of 1 cfu/ml was observed in T_2PS before storage but there was no fungal growth in wines after storage. The antimicrobial property of the wines may be due to the titrable acidity which ranged from 0.73 to 0.79 per cent and the alcohol content which ranged from 8.16 to 9.63 per cent after storage. Brathwaite and Badrie (2001) also observed a low microbial count of less than 30 colonies in all treatments of banana wines after storage. According to the authors, the inhibition of micro organisms were mainly due to low pH and high alcohol content which acted on microbial cell viability. The titrable acidity in banana wines are mainly contributed by malic, citric and succinic acids. In acceptable levels, these acids enhance the flavour and increase the palatability of wines and also play a preservative role by creating an unfavourable environment for different micro organisms that could cause spoilage.

Cost of production analysis of the most acceptable wine

The cost of 750 ml (one bottle) of banana wine worked out was Rs. 96/- as against Rs. 150 for 750 ml of grape wine available locally made by wine makers. In this study, banana was purchased from the local retail shops. Usually the grape wine makers purchase grapes from whole sale markets which considerably reduce the cost of production. The present cost of production of banana wine (Rs. 96/-) can be further reduced by purchasing banana from whole sale markets or directly from the farmers.

Wines especially with low alcohol content are gaining popularity among the consumers. Potential opportunities exist to develop and produce local fruit wines for consumption by both domestic market and tourists. Bananas (*Palayankodan*) can be used to produce an acceptable sweet wine with good shelf life using the pure strain MTCC 172 by increasing the TSS to 20° Brix by ameliorating with sugar and treating with 0.3 per cent commercial pectinase. This treatment has proved that *Palayankodan* is a vital substrate for wine making with good economic returns.

SUMMARY

SUMMARY

The present study entitled "Process standardisation for banana wine" was attempted to evaluate the physico chemical and sensory qualities of banana wines with different strains of wine yeast *Saccharomyces cerevisiae* and baker's yeast used for wine making. The study also aimed to evaluate the effect of various treatments, such as treatment with commercial food grade pectinase, potassium metabisulphite and pressure cooking of banana pulp on the quality aspects of the fresh and stored wines.

Three pure strains of wine yeast *viz*. MTCC 172, MTCC 174 and MTCC 180 procured from IMTECH and baker's yeast from the market were used for wine making. Each strain was used in two different dilutions (10^6 and 10^7) for fermentation of banana pulp. Banana variety *Palayankodan* was selected for wine making. Standardisation of inoculum concentration was done by standard procedure.

Banana wines were prepared using pure strains and also with baker's yeast each with 10^6 and 10^7 dilutions. Among the pure strains used for the preparation of banana wines, MTCC 172 showed significantly high wine yield in T_1 (59.53%) followed by T_2 (57.57%) in dilutions 10^6 and 10^7 respectively. Wine clarity was high in T_5 (78.92%) with the pure strain MTCC 180 (10^6 dilution). In the case of alcohol content, MTCC 174 showed the highest amount of alcohol (9.87%) in 10^7 dilution followed by 9.07 per cent in 10^6 dilution. The highest pH of wine (4.26) was observed with MTCC 174 (10^7) with a significantly low titrable acidity (0.53%) and a maximum TSS of 14°Brix. MTCC 172 (10^6) also produced wines with significantly high TSS (13.93°Brix) and a high pH (4.25). MTCC 174 (10^6) produced wines with the lowest TSS (11.93°Brix) and highest titrable acidity.

Among wines with baker's yeast, T_7 (BY 10^6) recorded highest wine yield (68.36%), alcohol content (8.23%) and TSS (12.46° brix) with a corresponding high titrable acidity of 0.89 per cent and low pH (3.74). Clarity was high (78.75%) in T_8 (BY 10^7). Sensory qualities of the wines showed that among pure strains, maximum score for colour and appearance (8.1), flavour (8.1) and taste (7.9) was for MTCC 172 in T_1 (10^6 dilution). Overall acceptability was also high in T_1 (7.8). Among wines

with baker's yeast T_7 (10^6 dilution) showed the best score for colour and appearance (8.4) and flavour (8.2) and an overall acceptability score of 7.6.

Based on the highest overall acceptability score, the pure strain MTCC 172 in 10^6 dilution and baker's yeast in 10^6 dilution were selected for standardising wines by different treatments of the substrate.

Eight treatments of banana pulp were tried for studying the quality of banana wines with the selected pure strain MTCC 172 (10^6 dilution) and also with the baker's yeast (10^6 dilution). Banana pulp was treated with commercial food grade pectinase and potassium metabisulphite (KMS). Pressure cooked bananas were also included as a treatment for wine making.

There was a significant increase in the wine yield in treatments except in T_5, T_6 and T_7. Among the banana wines prepared with the selected pure strain, higher wine yield (70.43%) was observed in T_7, which was prepared from the pressure cooked substrate treated with KMS.

Among wines with baker's yeast, T_4 (pulp + enzyme+ KMS) showed a significant increase in wine yield (81.94%) followed by 78.28 per cent in T_2 (pulp + enzyme), 71.36 per cent in T_6 (pressure cooked pulp + enzyme) and 70.61 per cent in T_3 (pulp + KMS). Wine yield was found to be higher in treatments with pectinase or KMS in both pure strain and baker's yeast wines.

Wine clarity was significantly high in T_8 (83.93%) where the pulp was pressure cooked and treated with enzyme and KMS. Treatments T_6 (pressure cooked pulp + enzyme) and T_4 (pulp + enzyme + KMS) also had a wine clarity (82.75 and (81.92%) comparable to that of T_8. With baker's yeast clarity was significantly high (86.08%) in T_6 (pressure cooked pulp + enzyme) and in T_8 with 84.75 per cent (pressure cooked pulp + enzyme+ KMS). Maximum clarity of wines were observed in enzyme and KMS treated samples in both pure strain and baker's yeast wines. There was no significant difference in wine clarity in each treatment with pure strain and baker's yeast.

A significant variation was observed in the alcohol content of wines with different treatments with pure strain compared to control T_1. Significantly high alcohol content of 10.26 per cent was observed in T_6 (pressure cooked pulp +

enzyme) followed by 9.40 per cent in T_2 (pulp + enzyme). In treatments with baker's yeast, a maximum alcohol content of 10.16 per cent was observed in T_5 (pressure cooked pulp) followed by 9.73 per cent in T_6 (pressure cooked pulp + enzyme) without significant variation. However there was no significant variation in alcohol content of each treatment between pure strain and baker's yeast. Alcohol content was also found to be more in enzyme treated samples.

Using pure strain, T_6 (pressure cooked pulp + enzyme) showed the least TSS (13.43°Brix) with a maximum alcohol content of 10.26 per cent, followed by 13.60°Brix in T_2 (pulp + enzyme) with an alcohol content of 9.40 per cent. Maximum TSS of 14.60°Brix was in T_8 (pressure cooked pulp + enzyme+ KMS). With baker's yeast, least TSS of 11.73°Brix was observed in T_6 (pressure cooked pulp + enzyme) with a high alcohol content of 9.73 per cent. TSS was significantly high in T_8 with pure strain compared to T_8 with baker's yeast.

In wines with pure strain, the treatment with lowest TSS (T_6) showed the maximum titrable acidity of 0.55 per cent with a corresponding low pH (3.95). T_2 (pulp + enzyme) with a TSS of 13.60°Brix also had the same titrable acidity with a low pH of 3.96. There was no significant variation in pH of the wines with pure strain but titrable acidity was significantly high in T_2 and T_6. In treatments with baker's yeast also, T_6 with a lowest TSS of 11.73°Brix showed significantly high titrable acidity (0.92%). T_5 (pressure cooked pulp) had the highest titrable acidity (0.94%) but without significant variation from T_6. There was no significant variation in the titrable acidity of wines except in T_1, T_5 and T_6 using pure strain and baker's yeast. Titrable acidity in these treatments were significantly high with baker's yeast, but pH of the wines were significantly low in treatments T_3, T_6 and T_8 with baker's yeast.

Organoleptic evaluation of the wines revealed that with regard to the colour and appearance of the wines prepared with pure strain, the mean score ranged from 7.2 to 8.1 maximum for T_1 (control). A high mean score of 8.1 was observed in T_1 with respect to flavour. The acceptability with regard to astringency was found to be highest in T_1 (7.0). Mean score for sugar acid blend was highest in T_2 (7.9) where the pulp was treated with enzyme. Regarding taste, highest score of 7.9 was observed in T_1 and T_2 and the lowest in T_7 (7.1). The acceptable level of alcohol strength was optimum in T_2 (7.9) and lowest in T_1 and T_3 (7.0). The score for overall acceptability

was found to be highest in T_2 and T_8 (7.9). Among the eight treatments prepared with pure strain, T_2 (pulp + enzyme) and T_8 (pressure cooked pulp + enzyme + KMS) were selected with the highest overall acceptability score and an alcohol content ranging from 8 to 12 per cent.

Organoleptic qualities of wines with baker's yeast showed that, the mean score for colour and appearance, flavour and acceptable level of astringency were highest in T_1 (8.4, 8.2 and 7.2 respectively), but with regard to sugar acid blend it was in T_4 (pulp+enzyme+KMS). Mean score for taste (7.8) was highest in both T_1 (control) and T_4 (pulp + enzyme+ KMS). Acceptable optimum alcohol strength (8.0) was in T_5 (pressure cooked pulp) followed by T_2 (7.8). Overall acceptability score was highest in T_2 (7.8) where the pulp was treated with enzyme followed by T_4 (7.7) where the pulp was treated with enzyme and KMS. Among the eight treatments prepared with baker's yeast, T_2 and T_4 were selected with maximum overall acceptability score and an alcohol content ranging from 8 to 12 per cent.

The selected wines (T_2 and T_8 with pure strain and T_2 and T_4 with baker's yeast) were pasteurised and bottled in amber coloured bottles with cork caps and stored in an ambient temperature for a period of three months. Physico chemical attributes, organoleptic qualities and microbial studies were conducted in the wines before and after storage.

With respect to the physico chemical parameters of the selected treatments with pure strain (T_2PS and T_8PS) and baker's yeast (T_2BY and T_4BY), a significant increase in the clarity of all the wines were observed after storage. Maximum clarity (87.42) was observed in T_8PS (pressure cooked pulp + pure strain + enzyme + KMS). However, among treatments, significant variation was not observed in the clarity of wines except for T_2PS (pulp+enzyme), where the clarity of wines were comparatively less initially as well as after storage. Initially, among treatments, the alcohol content of wines ranged from 8.00 (T_4BY) to 9.41 per cent (T_2PS) which increased from 8.16 (T_4BY) to 9.63 per cent (T_2PS). During the initial evaluation, alcohol content was significantly high in T_2PS (9.41%) when compared to other wine samples and the same pattern was also observed after storage (9.63%). But the increase in alcohol content in each treatment after storage was not significant.

A reduction in the TSS of all the wines were observed after storage. The initial TSS content varied from 13.60 to 14.23°Brix which decreased from 13.43 to 14.10°Brix. A corresponding significant increase in titrable acidity was observed in which the initial acidity varied from 0.43 to 0.55 per cent and the final titrable acidity varied from 0.70 to 0.79 per cent. The pH of the wines also showed a reduction after storage. But these quality parameters showed no significant variation with respect to treatments, after storage except in titrable acidity.

A reduction was also observed in the total sugar and reducing sugar content in wines after storage. Before storage, the total sugar content varied from 11.05 (T_2PS) to 12.96 per cent (T_4BY) and after storage it ranged from 10.24 (T_2PS) to 11.74 per cent (T_4BY), but the reduction was not significant in each treatment after storage. Lowest total sugar after storage (10.24%) was in T_2PS (pulp + pure strain + enzyme). Likewise the initial reducing sugar content varied from 2.89 (T_2PS) to 3.15 per cent (T_4BY) which decreased from 2.36 (T_2PS) to 2.91 per cent (T_4BY) after storage. There was a significant reduction in reducing sugar in all the treatments after storage. Lowest reducing sugar content was also in T_2PS after storage.

With regard to the tannin content, an increase was observed after storage. Initially tannin content of wine T_8PS (0.007mg/100ml) was significantly low and after storage also it was significantly low (0.014 mg/100ml) when compared to the other wines. The increase in tannin content in each treatment was significant after storage. Maximum tannin content after storage was observed in T_2BY (0.022mg/100ml).

With respect to the organoleptic quality attributes of wines after storage, there was no significant variation in the colour and appearance of the wines initially and after storage. A significant increase in the flavour of T_2PS (8.1) was observed after storage. A significant improvement was observed in the desirable level of astringency in wines, T_2PS (7.9) and T_2BY (7.2) after storage. Variation in the sugar acid blend of wines after storage was significant. Maximum score for sugar acid blend was for T_2PS (8.1), for taste T_2PS and T_2BY (8.2) and acceptable alcohol strength for T_2PS (8.0) followed by T_2BY (7.7). Overall acceptability was also high in T_2PS (8.1) followed by T_2BY (7.8) after storage.

The microbial study of the wines showed that initially the yeast count varied from 7 to $9x10^6$ cfu/ml the highest being in T_4BY. The bacterial population varied

from 1 to $3x10^3$ cfu/ml while fungi population was observed only in T_2PS ($1x10^3$ cfu/ml). After storage, there was no microbial population (yeast, bacteria and fungi) in the wines.

After storage T_2PS was selected from the stored wines with respect to the overall acceptability with an alcohol content of 9.63 per cent. T_2PS also gained the maximum score for optimum alcohol strength by the panelists. The selected wine was used for calculating the cost of production of banana wine. The approximate cost of the selected wine (T_2PS) was calculated based on the cost of raw materials and labour requirements used for the preparation of banana wine and this was then compared with the cost of 750 ml (1 bottle) of locally available grape wine prepared and sold by local wine makers. Grape wine (750 ml) costs Rs. 150 where as the costs of 750 ml of banana wine with *Palayankodan* cost only Rs. 96.00. Approximately the wine yield with one kilogram of banana is more than one litre (1.037 l).

The results of this study showed that use of commercial pectic enzyme in banana (*Palayankodan*) wine preparation produced wines with a fruiter flavour and sweet taste. The sensory evaluation revealed that the banana wines were of acceptable level. However to improve the wines in terms of palatability further studies can be done which may include blending of banana wine with other fruit wines prior to ageing. Similarly like yeast strain producing different quality attributes in banana wines, different varieties of banana in wine making can also be explored. The production of wines with different sensorial characteristics with different banana variety could be of great commercial interest since a range of consumers can be satisfied.

Banana is a highly perishable fruit. Though the fruit could be utilized for the preparation of jams, jellies etc, yet to accommodate the large quantities of the fruit produced during the glut periods, it becomes necessary to explore alternate methods for its utilization. Production of low alcoholic sweet wine from this fruit with attractive colour, flavour and taste is one of the profitable alternatives to utilize this fruit. If wine making from bananas can be explored commercially, it might ultimately reduce the annual wastage of bananas and also increase the income of banana farmers.

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*- Originals not seen

APPENDIX

APPENDIX – I

Score card for organoleptic evaluation of banana wine

Name of the judge:
Date :

Qualities	Score		
	1	2	3
Colour and appearance			
Flavour			
Taste			
Astringency			
Sugar acid blend			
Alcohol strength			
acceptability Overall			

9 point Hedonic scale

Colour and appearance, flavour and taste

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

Desirable level of astringency

Optimum	9
Acceptable	8
Good	7
Satisfactory	6
Bland	5
Slightly astringent	4
Moderately astringent	3
Highly astringent	2
Extremely astringent	1

Sugar acid blend

Optimum	9
Satisfactory	8
Slightly sweet	7
Moderately sweet	6
Neither sweet nor acidic	5
Slightly acidic/sour	4
Moderately acidic/sour	3
Highly acidic/sour	2
Extremely sweet	1

Acceptable level of alcohol strength

Optimum	9
Acceptable	8
Good	7
Satisfactory	6
Slightly alcoholic	5
Moderately alcoholic	4
Highly alcoholic	3
Extremely alcoholic	2
Non alcoholic	1

Signature:

PROCESS STANDARDISATION FOR BANANA WINE

By

SARITHA E V

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Home Science

(FOOD SCIENCE AND NUTRITION)

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF HOME SCIENCE

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR-680 654
KERALA, INDIA

2011

ABSTRACT

The study on "Process standardisation for banana wine" was undertaken to evaluate the physico chemical and sensory qualities of banana (*Palayankodan*) wines with pure strains of wine yeast *Saccharomyces cerevisiae* and commercial baker's yeast. Since, composition and quality of a wine was closely related to the yeast strain used, standardisation of banana wines with yeast strains was an objective of the study.

In the present study, three pure strains of *Saccharomyces cerevisiae viz* MTCC 172, MTCC 174 and MTCC180 were obtained from IMTECH and the commercial baker's yeast were used each in two different dilutions (10^6 and 10^7) for fermentation of banana pulp. Inoculum concentration was standardised by standard procedures before fermentation. 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 in both dilutions (59.53 and 57.57% respectively). MTCC 172 (10^6) also produced wines with significantly high TSS (13.93° brix) and high pH (4.25). Among wines with baker's yeast, T_7 (10^6 dilution) showed highest wine yield (68.36%), alcohol content (8.23%) and TSS (12.46° brix) with a corresponding high titrable acidity of 0.89 per cent and low pH (3.74). Clarity of wine was maximum (T_8) with baker's yeast (78.75% light transmittance) in 10^7 dilution. Sensory qualities of the wines with yeast strains revealed that the panelists were in agreement only with the high flavour profile of the wines. Among pure strain, MTCC 172 (10^6) dilution had the maximum score for colour and appearance (8.1), flavour (8.1), taste (7.9) and overall acceptability (7.8). Among wines with baker's yeast, T_7 (10^6 dilution) showed the best score for colour and appearance (8.4), flavour (8.2) and overall acceptability (7.6).

Based on the overall acceptability score of the wines, pure strain MTCC 172 (10^6 dilution) and baker's yeast in 10^6 dilutions were selected for wine development.

Another objective of the study was to evaluate the effect of various treatments on the quality attributes of wines developed by the selected yeast strains. Treatments with pectinase enzyme, potassium metabisulphite (KMS) and pressure cooking of banana pulp as a pretreatment were done to evaluate the quality aspects of wines.

Among treatments with MTCC 172, T_2 (pulp + sugar + PS + enzyme) and T_8 (pressure cooked pulp + sugar + PS + enzyme + KMS) were selected with maximum overall acceptability score (7.9). Among treatments with baker's yeast, the selected treatments with acceptable quality parameters were T_2 (pulp + sugar + BY + enzyme) and T_4 (pulp + sugar + BY + enzyme + KMS) with the highest overall acceptability score of 7.8 and 7.7 respectively.

All the four selected wines were treated with pectinase (0.3%).

The selected wines after initial quality evaluation were pasteurised and bottled in amber coloured bottles with cork caps and were stored in ambient temperature for three months for storage studies. The physico chemical characteristics of the wines showed a significant increase in clarity, titrable acidity, tannin and a significant reduction in reducing sugar. Maximum wine clarity, titrable acidity and maximum reduction in reducing sugar were found in T_2PS.

With respect to organoleptic qualities, there was no significant change with regard to colour and appearance, taste and overall acceptability of the wines in storage. A significant increase in flavour, desirable level of astringency and acceptable level of alcohol were observed in T_2PS (pulp + sugar + PS + enzyme) after storage.

Organoleptic qualities after storage revealed a high score for T_2PS in attributes like desirable level of astringency (7.9), sugar acid blend (8.1), taste (8.2), acceptable level of alcohol strength (8.0) and overall acceptability (8.1).

After storage there was no microbial population (yeast, bacteria and fungi) in the wines.

The cost of production of the selected wine treatment T_2PS (pulp + sugar + PS + enzyme) was worked out and was compared with the cost of 750 ml of grape wine locally available made by wine makers. Grape wine (750 ml) costs Rs.150/- whereas the banana wine costs Rs. 96/-. The cost can be reduced further in large scale production of banana (*Palayankodan*) wines.