STANDARDIZATION OF QUALITY WINE PRODUCTION FROM SELECTED UNDEREXPLOITED FRUITS.

by

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(2017-12-032)

THESIS

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN HORTICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF POST HARVEST TECHNOLOGY

COLLEGE OF AGRICULTURE

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KERALA, INDIA

2019

DECLARATION

I, hereby declare that this thesis entitled **"STANDARDIZATION OF QUALITY WINE PRODUCTION FROM SELECTED UNDEREXPLOITED FRUITS"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associate ship, fellowship or other similar title, of any other University or Society.

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Certified that this thesis entitled **"STANDARDIZATION OF QUALITY WINE PRODUCTION FROM SELECTED UNDEREXPLOITED FRUITS"** is a record of research work done independently by Ms. Keerthana Das (2017-12-032) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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ACKNOWLEDGEMENT

I owe a debt of gratitude to Almighty Lord for he has enlightened my path and his blessings which strengthened me to complete this journey successfully.

The words may fall in short to express my sincere and profound gratitude to my major advisor, ***Dr. Mini. C*** *Professor and Head, Department of Post Harvest Technology for her valuable guidance, support, warm encouragement and patience that I have experienced for the last two years. Thank you mam for your unconditional love, support and special care. I have been amazingly fortunate to have such an advisor who gave me the freedom to explore on my own and at the same time the guidance to recover when my steps faltered.*

I express my sincere and heartfelt gratitude to ***Dr. P.R. Geethalekshmi,*** *Assistant Professor, Department of Post Harvest Technology, for the timely advice, careful instructions, valuable suggestions and support provided during the course of work. I was very fortunate to get suggestions and advice from you.*

I convey my sincere thanks to ***Dr. Thomas George,*** *Professor, AINP on Pesticide Residue, for the valuable advice, suggestions and support during my study. I deem it my previlage in expressing my heartfelt great fulness to the member of my advisory committee* ***Dr. Anith K.N,*** *Professor, Department of Agricultural Microbiology for explicit instructions and valuable suggestions throughout my investigation.*

*I express my sincere gratitude to **Athulya Mam** Assistant Professor, Department of Post Harvest Technology, for her timely support and guidance during thesis preparation.*

*I express my heartfelt thanks to **Baby Chechi, Archana Chechi, Sreeja chechi, Manjusha chechi and Jinju chechi** for the timely support, care and love rendered during all stages of my research work. I avail this opportunity to thank my dear seniors **Athira chechi, Gana chechi, Thushara Chechi, Karishma chechi, Sonia Chechi, Anila chechi, Siji chechi, Bensi akka and Greeshma chechi** for their support, help, care, love and encouragement during my research work.*

*I am thankful to my dearest **Aparna Chechi** for her unconditional love, care, patience, and support that she gave me during the period. I express my heartfelt thanks to my batch mates **Lekshmi chechi, Archana and Swathi** for the support and love throughout these two years and the way they have spent their valuale time for helping me. I express my sincere gratitude to my dear roomie **Deepthi S Nair** and my loving friend **Unni** for their constant help, care, selfless support, positive energy and unconditional love that I have received in all my tough and good moments. I express my sincere gratitude to my best friends **Aishwarya, Aswathy, Krishnaveni and Bindhya** for their support, care and love during my studies and all my difficult period.*

*I express my sincere gratitude to my dear friends **Susan, Kavya, Anand, Ajmal, Anju, Greeshma, Riyas, Divya, Nandana, Jithoop, Thasni, Saranya chechi, Athira, Aiswarya, Arunima** for their company, support and inspiration. I profoundly express my gratefulness to my dear juniors, **Gayathri, Elso, Menaka and Aparna,** for their support and love.*

Words are not enough to express my whole-hearted and affectionate gratitude to my family my acha Yatheendra Das, amma Sheeja Das and my loving brothers Appu, Arbith, Ankith and Midhun for their unbounding love, unparallel affection and constant encouragement throughout my career and without whose invaluable moral support, the thesis would not have seen the light of the day.

I express my love and gratitude to my new family my loving husband Unni Ravi Sankar, achan Pushpakumar, amma Bindhu and my loving sister and brother Chippy and Kannan.

I bow to the lotus feet of the ***Almighty****, whose grace had endowed me the inner strength and patience and blessed me with will power to complete this endeavour successfully.*

Keerthana Das

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS

^0C	Degree celsius
%	Per cent
mL	Millilitre
L	Litre
ppm	Parts per million
CO_2	Carbon dioxide
CD	Critical difference
T	Treatments
CRD	Completely Randomized Design
et al.	And other co workers
Fig.	Figure
g	Gram
kg	Kilogram
mg	Milligram
^oB	Degree brix
viz.	Namely
$KMnO_4$	Potassium permanganate
NS	Non-significant
TSS	Total Soluble Solids

LIST OF APPENDICES

Introduction

1. INTRODUCTION

Analysis of processing and value addition sector in Kerala reveals that emphasis has been given only to the major fruit crops and the wealth of indigenous fruit crops has not been brought to the forefront. In the present scenario of changing food habits, job profile and health awareness, new, improved, nutritious and delicately flavoured processed products are in demand world over. To satisfy this demand, there is a constant search and effort to develop novel products from hitherto little sources. In this regard, India offers exciting possibilities of adding new dimensions to the food processing industry. Consumers today are becoming increasingly conscious of the health and nutritional aspects of their food. The tendency is to avoid chemicals and synthetic foods and choose therapy and nutrition through natural resources. Although, some fruits such as kokum (*Garcinia indica*) are explored for commercial processing, the nutritive and therapeutic advantages of several minor and underutilized fruits are to be exploited at their full potential by the processing industries.

A number of acceptable value added products can be prepared from under exploited fruits retaining their nutritional and medicinal properties. Many such preparations have been standardized, nutritional properties studied and storage requirements have been formulated to enable commercial exploitation. The potentiality of processed products from many minor fruits in the country is still untapped and remains to be unknown in world market which needs to be popularized. Fruit wines are one among them.

Wine resultsfrom alcoholic fermentation, a biochemical process in which yeast converts a carbohydrate such as starch or glucose, into ethyl alcohol anaerobically typically involving effervescence giving off of heat and modifying the physicochemical and sensory quality attributes especially aroma, colour and flavour of the produce.

Fruit wines are un-distilled fermented alcoholic beverages usually prepared from a variety of base ingredients other than grapes. They are nutritive, tasty and act as mild stimulants. Wines made from fruits are often named after the fruits, from which they are produced. Other than water and milk, no other drinks have earned such huge acceptance all over the world and esteem throughout the decades as has wine. Wine has flavour like fresh fruit, it can be stored and transported under normal conditions. Wine contains most of the nutrients in the original fruit juice since it is a fruit based, fermented and undistilled product. These fruits undergo fermentation and ageing for a period. They have an alcohol content ranging from 5 to 13 percent (Sandhu and Joshi., 1995).

By providing proper impetus to the wine production and marketing with suitable Government policy changes, it is possible for the farmers to get good remuneration to their produce. The economic security of Karnataka grape growers due to Karnataka grape processing and wine policy of 2007 is the typical example. Since the export prospects are huge, there is an opportunity always to get additional profit. Though many are producing wine from several fruits, the technology is to be standardized for a quality produce.

Homestead farming system is prevalent in Kerala with a variety of crops grown for food, feed, fodder and fuel, including many traditional fruit trees. But they are mostly neglected as the surplus generated could not be marketed due to low market price and high labour cost leading to wastage of fruits. The production under homestead is not efficiently used for consumption or value addition. Majority of these underutilized fruits are receiving attention in view of their tremendous medicinal and nutritive potential, but unknown to people rather than local and tribal people. Data regarding area and production of these fruits are still unavailable. Four different under exploited fruits varying in quality parameters viz., carambola, papaya, jamun and rose apple were selected for the study with the intention to formulate wines of varied quality.

Hence an experiment entitled "Standardization of quality wine production from selected underexploited fruits" was conducted with the objective to standardize wine production technology from selected underexploited fruits of Kerala.

Review of Literature

2. REVIEW OF LITERATURE

A number of acceptable value added products can be prepared from under exploited fruits retaining their nutritional and medicinal properties. Many such preparations have been standardized, nutritional properties studied and storage requirements have been formulated to enable commercial exploitation. The potentiality of processed products from many minor fruits in the country is still untapped and remains to be unknown in world market which needs to be popularized. Fruit wines are one among them. Important reviews on wine making, classification, fruit wines from under exploited fruits and the factors influencing wine quality are discussed in this chapter.

2.1. Wines

Fermentation is a viable technique in developing new products with acceptable sensory qualities like flavour and nutritional status (Jackson, 2000). One amongst the oldest fermented, traditional, alcoholic beverages of the mankind is wine (Blandino *et al.*, 2003).

Except water and milk no other drinks, have gained such universal acceptance as has wine (Mohan *et al.*, 2007). Wine contains most of the nutrients and bioactive components present in the original fruit juice (Joshi *et al.*, 2009). It is the oldest biotechnological method for producing and preserving food materials (Badola and Aitken, 2010).

According to Maragatham and Panneerselvam (2011) wine being the oldest fermented beverage was mentioned in the Bible and in other documents from Asian countries. Wines are undistilled alcoholic beverages made from grapes, they are nutritive, tastier and mild stimulants (Kelebek and Selli, 2011). The nutritive value of wine is due to release of amino acids and nutrients from yeast upon fermentation (Bhowmick, 2011).

Wine is a food with a flavour like fresh fruit which could be stored and transported under the existing conditions (Hazarika, 2014). Wine is considered as an excellent source for many bioactive compounds like antioxidants, polyphenols and flavonoids (Kumar *et al.*, 2016). Wine has a traditional importance in the development of mankind and cultures (Vazhacharickal *et al.*, 2016).

2.2. Classification of wine

Natural wines include dry wine, table wine, speciality wine, champagne, muscat etc while sweet wine, cherries, vermouth and port wines belong to dessert and appetizer wines (Amerine *et al.*, 1980).

Depending upon the time of fermentation, grape varieties used and colour of the wine, fruit wines are classified as red, white and pink wines. There are six major categories of red wines (Jackson, 2000). Dry wine is a type of wine where all fruit sugar is converted to alcohol during fermentation and had no residual sugar (Narain *et al.*, 2001).

Wines are of different types namely red, white, rose, sparkling and specialty wines (Joy, 2003). Grape wine is made exclusively from grapes and prohibited from using any other materials (exception is made only for sugar and oak barrels) during the wine production procedure (Carluccio *et al.*, 2003).White wine is not white; it is often yellow, gold or straw coloured. White wine is produced by the fermentation of the pulp of green or gold coloured grapes or from juice of red grapes, of Europe, and other places such as Australia, California, New Zealand and South Africa etc. Pink wine with a light pink colour, is produced using grape skin removed immediately after the start of the fermentation process. These are made using a mixture of "black" and "white" grapes. (Reddy and Reddy, 2005).

Light wine contains 7-9% alcohol and medium wine contains 9-16% alcohol (Singh and Singh, 2006). Based on various attributes such as cultivar, ripeness of fruits, chemical composition of fruit juice, use of additives, wine making techniques, ageing, the alcohol and sugar content, the wines are classified into natural wines with 9-14 % alcohol and dessert and appetizer wines with 15-21 % alcohol (Bisson and Butzkc, 2007).

Dry wines are the wines with very high alcohol and tannin contents, they have a characteristic spicy flavour (Swami *et al.*, 2014). They have also classified wines into table wines and fortified wines. Table wines are dry (sugar- 0.3 % and alcohol 9-14 %), semidry (sugar- upto 0.5- 3% and alcohol 12.9%) and sweet (sugar- upto 3- 8 % and alcohol 12.9 %). Whereas, fortified wines are strong (sugar- upto 1- 4 % and alcohol 17- 20 %), dessert sweet (sugar- upto5- 12 % and alcohol 14- 16 %), sweet (sugar- 14- 20 % and alcohol 15- 17 %), liqueurs (sugar-upto 21-35 % and alcohol 12- 17 %) and flavors (sugar- up to 6-16 % and alcohol 16- 18 %).

Wine contains ethyl alcohol, higher alcohols, acids, sugar, aldehydes, esters, tannins, amino acids, minerals, vitamins, anthocyanins, flavouring compounds etc. (Gaikwad *et al.*, 2016).

2.3. Wine making technology

The wine production techniques used for other fruit wines resemble those for the wine production from white and red grapes (Hale et al., 1999). Winemaking has mainly three operations, viz: pre-fermentation, fermentation and post fermentation operations (Jackson, 2000).

In white wine, juice or pulp is separated from the skin but in red wines the skin is not removed (Ribéreau-Gayon *et al.*, 2000). Juice clarification for white wine is usually achieved by settling or centrifugation of the must or juice followed by addition of yeast to clarified juice to begin fermentation (Jongen, 2002).

In the case of grape wines, pre-fermentation involves crushing and releasing juice from the fruit. Fermentation converts the sugars to alcohol and carbon dioxide by the metabolism of yeast. Incomplete or slower fermentation occurs when yeasts do not utilise the available sugar completely. Clarification is achieved by racking, filtration and/or centrifugation. Fermentation occurs in anaerobic conditions and is boosted with di-ammonium phosphate (DAP) to supplement nitrogen required for yeast growth in non-traditional methods of winemaking. Once the fermentation is complete post fermentation practices are done (Mintel, 2009).

In the case of red wine, the pulp, skins and seeds of grapes are kept together during crushing and fermentation. This is done to completely extract colour and flavour. Yeast is added to mashed pulp during winemaking (Balaswamy *et al.*, 2011).

According to Joshi *et al.* (2013), the process of fermenting is basically feeding sugars and nutrients in solution to yeast, which in return produces carbon dioxide gas and alcohol. This process goes on until either all the sugar is gone or the yeast can no longer tolerate the alcoholic percentage of the beverage dry wine.

The wine may be filtered, cold stabilised, fined and/or blended during the storage period, Fining agents such as enzymes, bentonite, diatomaceous earth, egg albumen etc. may be added to aid in clarification of wines. Wine undergoes several changes during ageing and at appropriate time, the wine is filtered and bottled (Joshi *et al.,* 2013).

2.3. Underexploited fruits and their potential

Underexploited fruits are with inherent potential for producing a range of novel products both industrially and nutritionally important and thereby finding use in human diet as neutraceuticals (Hiremath *et al.*, 2006).Small fruit size, short period of harvest, high picking frequency, low market demand and distant markets etc are the factors leading to their low economic values. Thus product diversification of underutilized fruits is an effective method to reduce their post-harvest losses (Choudhary *et al.*, 2006).Lack of processing technology is not a limiting factor for the minor fruits but the availability of surplus quantities is the main cause (Tandon and Kumar, 2006).

The major underutilized fruit trees in Kerala includes Jack fruit, Bilmbi, Indian plum, Java apple, Jamun, Goose berry, Pomelo, Malay apple, Kokum, tamarind (Peter and Abraham, 2007; Mohan *et al*., 2007; Kruijssen *et al*., 2009). Jamun is popular for wine making among consumers due to its balanced sugar, acid and tannin content (Das, 2009).

Underutilized fruits have a very important role to reduce malnutrition in both developing and under developed nations (Gebauer *et al*., 2007: Badola and Aitken, 2010). Most of these fruits are rich in antioxidents, organic acids, vitamins, and phenolic contents (Pande andAkoh, 2010; Kelebek and Selli, 2011).

Wine production from indigenous underexploited fruits is an important way to minimize the losses of excess fruit or to improve its palatability (Bolarin *et al*., 2016).

The tropical fruit papaya (*Carica papaya)* is a good source of carbohydrate, vitamins and minerals especially copper and magnesium (Wall, 2006). Papaya fruits contain components that can increase the total antioxidant power in blood (Ozkan *et al*., 2011). Sugars present in the fruit is used by microorganisms for wine production and Ayanru *et al.,* (1985) showed that yeast has a capacity of generation of ethanol by microbial conversion of sugar in papaya fruit.

2.4. Wines from underexploited fruits

Fruits having balanced sugar, acid, tannins and nutritive salts acts as a suitable substrate for yeast along with adequate quantity water is used for wine production (Robinson and Harding, 2006). Fruit wines contain 2 to 3 per cent sugar and 8 to 11 per cent alcohol with energy ranging between 70 and 90 kcal per 100 mL (Kundu *et al*., 1976).

Tropical underexploited fruits such as jackfruit and cashew apple were found to be suitable for wine production, mainly because of their availability, appropriate taste, high sugar, flavour, water contents and overall chemical composition (Ward and Ray, 2006; Mohanty *et al*., 2006).

Pande and Akoh (2010) reported that wine could be prepared from nutritionally diverse, highly perishable, underutilized tropical fruits, thereby helping efforts to increase shelf life by reducing post-harvest and production losses, improve nutritional value of fruits, increase cultivation and commercialization of fruits as well as to generate profits to growers and the existing wine industry.

Dry, semidry, or sweet wines of acceptable quality were produced from carambola. Thin Layer Chromatography (TLC) carried out by Napahde *et al*., (2010) revealed that the predominant sugar in the carambola juice is the fermentable sugar (sucrose).Wines made from a fruit is named after the fruit (Hajizadeh and Kazemi, 2012).

According to Bhaskar and Shantaram (2013) sucrose present in carambola fruit could support the growth of ethanol fermenting microorganisms but the amounts of these sugars present were reported to be however, too low for adequate alcohol production, to call the product a wine.

Jamun wine is known to have neutraceutical and therapeutic values (Jackson and Lombard, 1993).Chaudhary *et al.* (2014) opined that under exploited fruits like jamun can be used for wine making. The jamun wine was reported to have 6.6 to 9.0°Brix and 6.6 to 7.5 per cent alcohol by Gaikwad et al. (2016).

The finest raw material for winemaking has been the grape from time immemorial, although there have been several attempts to process wines from less utilised fruits (Paul and Sahu, 2014).Fruit wines are beverages made from base ingredients other than grapes they may have additional flavors from fruits, flowers, and herbs (Ghosh et al., 2017).

The fermentation condition of mulberry wine was standardized by Wang *et al.* (2013).Method of preparing bael fruit wine was developed by Panda *et al.* (2014). Caoli and Magsino (2017) reported that wine from both fresh and sterilized bilimbi (kamias) were sweet in taste.

Umeh *et al* (2015) prepared papaya wine with a brilliant yellow color and a slight sweet flavor with an alcoholic content of 10.14%. Simenthy (2015) standardized a method for making wine from nutmeg rind.

Rose apple juice and rose apple wine are the two major products that can be produced from rose apple fruits (Bolarin *et al.*, 2016).

2.5. Biochemical characteristics of wines

Polyphenols are related directly to the characteristics of foods, such as taste, palatability, nutritional value, and have particular importance for the characteristics and quality of red wines (Blois, 1956). Polyphenols determine the wine properties like color, bitterness and astringency (Singleton *et al.*, 1965). Tannin content of carambola wine ranged from 51.20 to 66.10mg/l according to Chikkasubbanna *et al.*, (1990).

Wines prepared from mixtures of blackcurrants and redcurrants and of blackcurrants and bilberries showed high antioxidant activity (Halliwell, 1996). Heinonen *et al.* (1998) found that berry wines possess antioxidant activity with reference to methyl linoleate oxidation, wines prepared using crowberry and blackcurrant are slightly superior to red grape wines. Single wines made of cranberries (92%), crowberries (98% inhibition), rowanberries (90%), liquor of arctic bramble (78%), cowberries (69%), and apple (84%) were found to be efficient antioxidants.

Blueberry wines showed very high hydroxyl radical scavenging activity compared to other wines (Pinhero and Paliyath, 2001).

Antioxidant activity of white wines is found to be comparatively lower than the activity of red wines due to their lower phenolics content (Abu-amsha *et al.*, 1996). White wine with low phenolics had zero effect on the oxidation of MeLo (methyl linoleate) and fruit wines with a phenolics less than $<$600mg/L GAE did not inhibit oxidation of MeLo (Gumienna *et al.*, 2011).

Alcohol content in mango wine belonged to the range of 5- 13% and to the phenol content was lower according to (Akingbala *et al.*, 1994). According to them the acidity of mango wine was 0.38% (expressed in terms of citric acid).

Akingbala *et al.*(1994) reported that banana wine had an ethanol content of 13.98% (v/v). According to Kotecha *et al.*, (1994) banana wine had a TSS content of 10.2 °Brix and acidity of 0.88%.

The quantity of phenolic materials present in a wine vary considerably in different types of wine, depending on the fruit variety, environmental factors in the vineyard, and wine processing techniques (Frankel *et al.*, 1995).

Free radical scavenging activity of berry-fruit wines is found to be because of the polyphenol content, mainly anthocyanins (Heinonen *et al.*, 1998).

Anti-oxidant, anti-inflammatory and anti-microbial activity etc are shown by the polyphenolic compounds like resveratrol, hydroxytyrosol, quercetin and phenolic acids present in the wine (Jackson, 2000). They show antioxidant properties because of their redox properties, which make them act as reducing agents, hydrogen donors, singlet oxygen quenchers, metal chelators etc (Landbo and Meyer, 2001).

Akubor *et al.* (2003) reported that banana wine produced had a reducing sugar content of 3.18% and tannin content of 0.044%.

Tsai *et al.* (2004) reported that mulberry wine has a pH and alcohol content of 3.7 and 12% respectively.

Flavonoids contribute to antioxidant properties of red wine. 15 anthocyanins and 10 flavonoids are found in 34 French wines prepared from six grape varieties and three growing areas in France (Yao *et al.*, 2004).

According to the study conducted by Chinjirakul *et al.* (2007) fruit wines have a higher antioxidant activity than the original fruit.

The antioxidant capacity of wines is because of the bioactive molecules called polyphenols especially anthocyanins. The antioxidant activity of wines is attributed by bioactive compounds especially polyphenols (Rivero Pérez *et al.*, 2008).

The acceptability of wine is mostly influenced by its alcohol content. Amino acid biosynthesis from carbohydrates or deamination or decarboxylation of existing aminoacids bring about alcohol in wines (Sharma and Bhat, 2009). Cherry wine has high antioxidant potential (Yoo *et al.*, 2010).

Awe (2011) reported a drop in sugar from 15 to 1% during the aerobic fermentation of papaya. Acidity of wines lies between pH 3 and 7 for dry wine and 3.5 to 4.5 for a sweet wine.

Polyphenolics are a large and complex group of compounds. They are responsible for the characteristics, colour, flavour and quality attributes of fruit wines (Mudnic *et al.*, 2012).

Herbal wines from wild berry fruits with 8 to 10°Brix had 10-15 % alcohol and 3.5 to 3.8 pH. (Rana and Singh, 2013).

According to Awe (2014), aerobic fermentation, caused the pH drop from 4.4 to 3.1, titratable acidity increase d from 0.2 to 0.4 % in papaya wines. Panda *et al.* (2014) said that the wines produced from fruits rich in antioxidants have an alcohol content of 7.87 per cent.

Acidity content of the rose apple wines ranged from 0.28 to 0.69%. Swami *et al.* (2014) reported that rose apple wines contain an alcohol per cent of 8 to 11%.

Simenthy (2015) reported that nutmeg wine has total phenol content of 0.99 mg g-1.

Wine sensory properties including aroma and appearance is contributed by polyphenols and they also play an important role in their medicinal importance as antioxidants, and preventing coronary heart disease (Sun *et al.*, 2015).

Vazhacharickal *et al.* (2016) reported that Gooseberry wine recorded a total acidity of 8.26 ± 0.015 % on 20 days of fermentation and Bilimbi recorded 0.39 ± 0.014 % after 20 days of fermentation. They reported that highest alcohol contents were in the order Bilimbi (0.39 ± 0.014)> Java Apple > Ginger > Gooseberry > Coffee > Pepper (0.25 ± 0.009). Gooseberry samples showed highest vitamin C content (12.73 ± 3.60) while least with Ginger samples (1.13 ± 0.12). The jamun wine was reported to have 6.6 to 9.0° Brix and 6.6 to 7.5 per cent alcohol by Gaikwad *et al.* (2016).

Kumar *et al.* (2016) reported a phenol content 226 mg l^{-1} in custard apple wine.

Polyphenols affect the sensory properties of the wine due to their interaction with proteins, other polyphenols and polysaccharides this interaction al so alter the chemical properties of wine (Sabat*et al.*, 2016).

Budak (2017) studied the bioactive components of *Prunus avium* L. Black gold (red cherry) and *Prunus avium* L. Stark gold (white cherry) wines and found that the former is having a phenol content of 450 mg GAE L^{-1} and latter with 350 mg GAE L^{-1}.

2.6. Factors affecting wine quality

Wine quality is dependent on the substrate, content of sugar, yeast strain, storage conditions and climatic conditions (Esteves and Orgaz, 2001 ; Jones and Davis, 2000). Fermentation is managed by winemakers by controlling different parameters such as skin contact time, temperature, pressing technique used, etc (Bolarin *et al.*, 2016).

2.6.1. Fruit: Water Ratio

Kundu *et al* (1976) prepared banana wine with three different dilution ratios of 1:0, 1:1 and 1:2 and observed inverse relation in the case of polyphenol and alcohol content with dilution whereas sugars varied directly with dilution.

Rate of fermentation is reported to increase with increase in dilution level due to the better fermentation conditions in the must such as initial aerobic conditions needed for the yeast growth and optimum pH as a result of dilution of thick pulp (Joshy *et al.*, 2012).

Joshi *et al.* (2012) found jamun wine prepared by 1:1 dilution as the best on the basis of physical, chemical and sensory quality characteristics but Jamun must prepared by 1:2 dilution gave better fermentation behaviour. With the increase in dilution level, TSS, titratable acidity and sugar content decreased.

Simenthy (2015) reported that wine prepared using nutmeg rind, sugar and water in the ratio 1:1:1 was found to be best after biochemical estimation and organoleptic evaluation.

Pink rose apple wine prepared from sliced fruit: sugar: water in 1:1:1 scored highest score for taste in sensory evaluation (Bolarin *et al.*, 2016).

2.6.2. Sugar content

Amerine *et al.* (1980) reported that that the juices obtained from the fruits other than grapes have a lower sugar content and higher acid content which is solved by adding water to dilute the excess acid followed by addition of sugar.

Tannin and phenol content increased in the carambola wine with higher TSS level. Tannin content of wine ranged from 51.20 to 66.10mg/l. This result is in conformity with Shukla and Revis (1985).

Lewis and Grocizam (1989) reported that some sweet cultivars of carambola are said to have high carbohydrates (specifically glucose) content and pH around 4, which make their wine more feasible.

Lakshmana *et al.* (2006) had also reported that the wine prepared from the 24^0 Brix must of carambola fruit has acceptable sensory qualities supported by different physical and chemical characters.

Kumoro *et al.* (2012) studied the effect of juice sugar content on quality of jackfruit wine and reported that 14%W/W of sugar concentration for 9 days produced the best quality jackfruit wine.

Herbal wines from wild berry fruits with 8 to 10° brix had 10 to 15 per cent alcohol and were rated acceptable with good sensory scores for colour, taste, sweetness and astringency (Rana and Singh, 2013).

Valim *et al.* (2016) standardized the best conditions for the production of carambola wines as intial solube solids between 23.8 and 25^0 Brix and initial concentration of yeast between 1.6 and 2.5g L^{-1}.

When dealing with fruits other than grapes, sugar may need to be added to spur the fermentation process in the event that the fruit does not contain enough natural sugar to ferment on its own in the presence of yeast (Saranraj *et al.*, 2017).

2.6.3. Acidity

Shukla *et al.* (1991) had reported high acidity and tannin content in jamun affect the rate of fermentation and finally the quality of jamun wine. High acidity of carambola fruits affect their fermentation and hence the quality of the final product.

Malic acid, one of the biologically fragile wine acids is high in rose apple juice and it is easily metabolized by several different types of wine bacteria (Lum, 1998).

During the fermentation process, acidification of the medium occurs which is crucial for wine production (Ross, 1999). Lack of acidity will cause poor fermentation (Berry, 2000).

Acidity plays an important role in the wine quality by helping in fermentation process and improving the overall characteristics and balance of the wine (Ozkan *et al.*, 2011). The composition of organic acids is a crucial trait that determines the acidity of the wine (Das *et al.*, 2012).

Wang *et al.*(2013) reported that, a pH of 3.2, fermentation temperature of 31.4°C and six days' fermentation time were optimal for mulberry fermentation.

Malic acid is weaker than tartaric acid, so wines unusually high in malic acid can have a high titratable acidity and a high pH value. This was in line with the findings of Vazhacharickal *et al.* (2016) who reported that the acidity of rose apple wine was 5.69 ± 0.026 % after 20 days of ageing.

2.6.4. Yeast concentration and yeast strain

Yeast inoculum level significantly affected wine fermentation. It shortened the fermentation time. The non-saccharomyces yeasts disappeared quickly with increasing inoculum size (Erten *et al.*, 2006).

The interaction of inoculum level of wine yeast, fermentation time and temperature was found to be significant in influencing the wine quality (Borate *et al.*, 2008).

Obaedo and Ikenebomeh (2009) reported that in a comparison between *Saccharomyces cerevisiae* and *Schizosaccharomyces* species for production of mango wine it was found that the former produced dry wine whereas the later produced sweet table wine respectively.

Sevda *et al.* (2011) reported that *Saccharomyces cerevisiae* NCIM 3283 and NCIM 3046 produce banana wines having good qualities in terms of flavour, taste, clarity and overall characteristics.

Ivanova *et al.* (2011) reported that the concentration of yeast does not affect the phenol content of Chardonnay wines.

Appearance along with clarity or brilliancy is a good indicator of wine quality and the yeast has important role in fermentation of fruits and fruit wine quality (Chira, 2012).

Kumoro *et al.* (2012) studied the effect yeast strain on quality of jackfruit wine and reported that 0.5% W/V of yeast for 9 days produced the best quality jackfruit wine.

In a study by Swami *et al.* (2014) sugar conversion was incomplete in rose apple wines at yeast concentration of 0.1%.

Musyimi *et al.* (2013) reported that increase in yeast concentration and temperature increased fermentation kinetics if apple mango wine. They found that the optimum yeast concentration and temperature for apple mango wine is 0.05% and 25^0C respectively.

Valim *et al.* (2016) reported that initial conditions of 23 to 25°Brix, 4.8 to 5.0 pH and 1.6 to 2.5 g L-1 of yeast concentration produced quality wine from star fruit.

The average sugar content of rose apple fruits varied between 2.07 and 2.53% (Bolarin, 2016) which is very low for conversion to alcohol content.

The higher yeast count helped in faster fermentation as suggested by Chaudhary *et al.* (2017).

Chaudhary *et al.* (2017) found that the best treatments for preparation of jamun wine were strain 4787 of S. cerevisiae at an inoculum level of 7.5% and a fermentation temperature of 25°C. It was observed that fermentation in jamun wine was faster in fermentation medium inoculated with 7.5% yeast concentrationcompared to 2.5%. They also found that strain S. cerevisiae 4787, 7.5% inoculum level produces the best jamun wine.

2.6.2. Enzyme treatment

Akingbala *et al.* (1994) reported that pectinase enzyme (0.5%) when added to the mango pulp produced wine of desirable sensory attributes.

Kotecha *et al.*(1994) found that 0.2% pectinase enzyme is ideal for treating bnna must during wine production.

Sevda *et al.* (2011) reported that use of pectinase enzyme produce better quality wine from banana as compared to wine produced without enzyme treatment.

Enzymes are natural and fundamental elements in the winemaking process. They occur naturally in wine grapes and yeast, commercial enzymes are commonly added in production of fruit wines (Ivanova *et al*., 2012).

They can be used to improve extraction and the aromatic profile of a wine, while also accelerating the winemaking process (Chakraborty *et al*., 2014).

2.7. Sensory Analysis

The successful sensory evaluation in food industries is achieved by linking sensory properties to physical, chemical, formulation and process variables which enables manufacturing food products with maximum consumer acceptance. It is frequently used in food industries for new product development and recipe modification of the products (Chikkasubbanna *et al.*,1990).

It is carried out to find out differences among the products, nature of difference and possible acceptance or rejection of products on the basis of differences (Renaud and DeLorgeril, 1992).

Sensory evaluation plays a significant role in quality control and marketing of the products (Betes- Saura *et al.*, 1996).

According to Chowdhury and Ray (2007) sensory evaluation score of the jamun wine were quite acceptable as a wine, but there were significant differences ($P< 0.05$) between the commercial grape wine and jamun in terms of particularly in taste, after taste and flavour mainly because of the high tannin in the jamun wine.

Sensory analysis of jamun wine showed that the panelists rated inferior (except colour/appearance) to commercial grape wine but the attributes like aroma, taste, after taste and colour/appearance were liked much by the panelists (Chowdhury and Ray, 2007)

Success of any value added product depends on its final acceptance by the consumers. No food or beverage is worth producing, distributing, or marketing without having an approximate idea that its sensory quality is accepted by consumers (Tuorila and Monteleone, 2009).

According to Joshi *et al.*(2012) jamun wine made with 1:1 dilution was found to be best with good sensory qualities.

Herbal wines from wild berry fruits with 8 to 10° brix had 10 to 15 per cent alcohol and was rated acceptable with good sensory scores for colour, taste, sweetness and astringency (Rana and Singh, 2013).

Paul and Sahu (2014) reported that the carambola wine possessed very good taste, aroma and clarity with moderately good body and aftertaste.

In a study conducted by Vazhacharickal *et al.* (2016) the sensory evaluation varied widely among the different wine samples. The overall acceptability was high for Gooseberry wine which was closely followed by Bilimbi and Java Apple wines respectively. In Coffee wine sour taste over dominated that of Ginger and Pepper wines.

Sensory evaluation is categorized into objective, where hedonic response of a product is determined by skilled evaluators whereas in subjective testing, consumers are involved in the evaluation process. Hedonic assessment is the economical and ideal method to find out the influence of variations in ingredients, manufacturing, wrapping, or shelf life (Sharif *et al.*,2017).

Caoli and Magsino (2017) compared the sensory attributes of fresh and sterilised bilimbi wines and found that aroma of fresh wine is fruity while it is powerful in sterilised wine. Moreover, appearance of fresh wine is dull and cloudy, while light pale in sterilized carambola.

The appearance of a wine being brilliant is a direct result of the wine style and the way the wine was made, filtered and bottled, and is not a characteristic of the varietal (Saranraj *et al.*, 2017).

2.7. Storage

The phenol content of carambola wine decreased at the end of storage (Wildenradt and Singleton., 1974).

The alcohol percent of the grape wine increased due to a decrease in total soluble sugars due to the activity of yeast during fermentation (Chikkasubbanna *et al.*, 1990). This happens as a result of oxidation of flavanols and flavan-3-ols. Decreased phenolic content is presumably a result of oxidation of phenolic compounds and their degradation leading to changes of their content by loss of reactive hydroxyl groups (Singleton *et al.*, 1999).

It is a very sensitive and complex combination of chemical components. Jones and Davis (2000) reported storage conditions as one of the factors influencing the wine quality.

The TSS of strawberry wines from the cultivars – Camarosa (9.8 to 9.6°Brix) and Doughlas (9.1 to 8.6°Brix) decreased during storage of three months (Sharma and Joshi, 2003).

Wine is a commodity that can improve in flavour and value with age, but it can also rapidly deteriorate if kept in inadequate conditions (Robertson, 2006).

Lakshmana *et al.* (2006) had also reported that in the wine prepared from carambola fruit sugar content decreased during storage while alcohol content increased during storage.

The polyphenol content decreased during storage mainly because of the decrease in monomeric anthocyanins whereas the copigmented and polymeric anthocyanins increased leading to an increase in antioxidant activity of mulberry wines. The organoleptic properties and sensory attributes of fruit wines are largely influenced by the polyphenolic content of the wine but being highly unstable the polyphenolic components in wine undergo several changes during wine storage including polymerisation, co-pigmentaton and oxidation (Fang, 2008).

Moisture content of the surroundings were wine bottles are stored play an important role in the quality of wine since too dry atmosphere causes the cork to dry up leading to shrinking of cork and entry of more air into the wine bottles (Chung., 2008). Kallithraka *et al.*(2009) stated that the phenol content decreases during storage in Chardonay wines.

During wine storage rearrangement occurs between phenolic compounds which causes polymerisation in wines. When wines are aged in bottles, oxidative

37

reactions occur if bottle closures allow oxygen into the wine (Chira, 2012). Storage conditions viz., light and humidity including wine packaging and storage temperature are the most significant factors that have the most direct impact on a wine's quality.

The polyphenol content of wines decreases during storage as stated in literature (Ivanova *et al.*, 2012).

Compared to clear light containers, dark coloured containers for eg. amber and green offer greater protection from light. Direct sunlight through plain glass bottles can adversely react with phenolic compounds in wine and create "wine faults". Amber coloured bottles prevent wines from sunlight and oxidation thus retaining taste and preserving antioxidants and its polyphenols. A significant loss in the wine aroma occurs due to absorbtion by plastic containers thus according to Revi., 2014 wine storage is ideal in dark coloured glass bottles.

An 'ideal' storage temperature for wine is a myth because the wine development is a complex process yet to be deciphered. Low temperature (e.g. $<$ 10°C) will reduce the risk of spoilage, but the wine will require a longer time to develop (Scrimgeour., 2015).

The effect of maturation on physico-chemical and sensory quality characteristics of custard apple wine was studied by Kumar., (2016). The study revealed that the TSS content was reduced to 9.87°Brix and 9.63°Brix three and six months after storage respectively from 10.13°Brix. They had reported a significant decrease in phenol content of custard apple wine during storage. The total phenol content was 226 mg l^{-1} initially which was reduced to 175 mg l^{-1} after six months of maturation period.

Protection and maintenance of characteristic quality parameters of the food and drinks is the main aim of packaging. Packages act as barrier to oxygen, moisture, light, carbon dioxide and aroma of wine. For wine the classic packaging is glass, the advantages being its clarity and inactive nature (Grant-Preece, 2017).

Sebastian (2017) evaluated five accessions of sweet lovi-lovi (*Flacourtia* spp.) for wine preparation and found that all the attributes of wine showed an increasing trend during storage. Formation of protein- tannin complexes has also been shown to contribute towards a decrease in phenolic content of white wine. Increase in alcohol content was reported in sweet lovi-lovi wines during three months of storage

Materials and Methods

3. MATERIALS AND METHODS

The experiment on "Standardization of quality wine production from selected underexploited fruits" was conducted at Department of Post Harvest Technology, College of Agriculture, Vellayani, Kerala Agricultural University, Thiruvanathapuram during the year 2017-2019, with the objective to standardize quality wine production technology from selected underexploited fruits of Kerala. The materials used and methodologies adopted for the research programmes are described in this chapter.

3.1.1. Selection of fruits

The following four different underexploited fruits (Plate 1.) were utilized for the programme. Ripe, fresh and good quality fruits were collected from the Instructional Farm, College of Agriculture, Vellayani or procured from farmers' fields

1. *Carambola (* Averrhoa carambola *)*
2. Papaya (*Carica papaya* L.)
3. Jamun (*Syzygium cumini* L.)
4. Rose apple (*Syzygium aqueum*)

3.1.2. Fruit wine preparation

Wine preparation was carried out in two different continuous steps

1) Primary fermentation
2) Secondary fermentation (Ageing)

Both primary and secondary fermentations were carried out in sanitized clay pots.

The collected fruits were cleaned, washed, inedible parts removed, crushed and filled in sanitized clay pots. Seeds were retained in case of jamun. Carambola fruits were subjected to hot water blanching at 100^0C for two minutes. Crushed fruits and Lukewarm water were mixed in three different w/v ratios.

R_1- 1:0.75 w/v

41

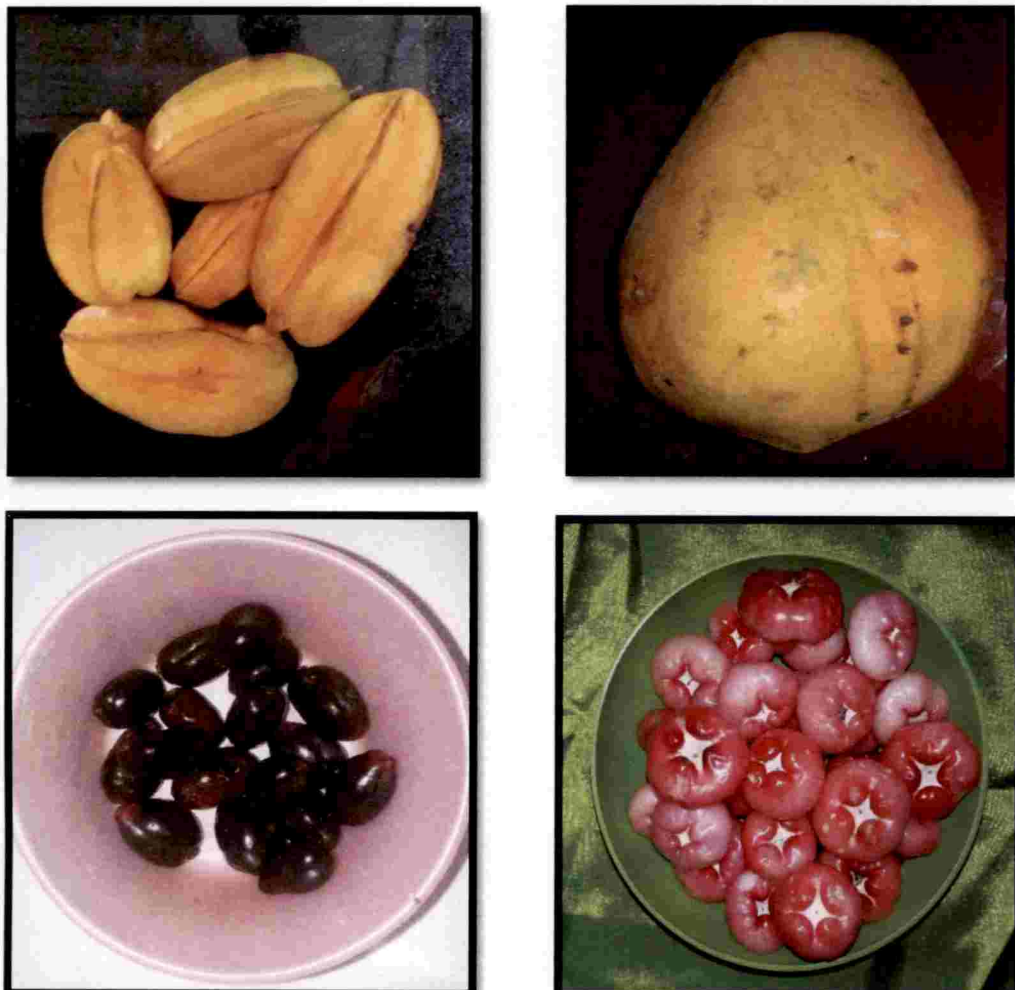


Plate.1. Fruits selected for wine preparation

R_2- 1:1 w/v

R_3- 1:2 w/v

Initial TSS of the fruit-water mix (must) was recorded using hand refractometer and TSS of the mix was maintained initially at 20^0brix by adding refined sugar. The inoculum, baker's yeast (*Saccharomyces cerevisiae*) was added to the mixture in the form of starter solutions in the following three different concentrations

C_1- 0.5% w/w

C_2- 0.75% w/w

C_3- 1% w/w

Starter solution was prepared by mixing yeast with sugar and lukewarm water. Handful of crushed wheat was added to the mixture to act as a source of food material to the yeast. Potassium meta bisulphite (KMS- 126g/kg) was added to the mixture @ 50-70 ppm SO_2 in order to control the wild yeast and undesirable bacteria. Primary fermentation was carried out for a period of 21days and end of froathing indicated the end of primary fermentation. During primary fermentation the content was stirred on alternate days to give uniform aeration and for maintaining the adequate temperature. The alcoholic ferment produced after primary fermentation was filtered and subjected to secondary fermentation for a period of another 21 days.

Clarification treatments were done during secondary fermentation using the following two methods

Cl_1- Pectinase @ 5 mg/l (TCI- AJEYH-FF-25mg)

Cl_2- Clarification by settling

After 21 days of secondary fermentation the resulting fruit wine was filtered, pasteurized at 80- 85 ^{0}C for two minutes and bottled in glass containers.

Fruit – Water ratio - 3

Yeast concentrations - 3

Clarification treatments - 2

Total number of treatments - 3 x 3 x 2 = 18

Replication – 2

Design - CRD

Experiment was conducted for each of the four fruits separately. Flow chart for preparation of fruit wine is shown in Fig (1).

Best wine was selected from each fruit based on physical, chemical and sensory quality parameters.

3.2. QUALITY ANALYSIS OF FRUIT WINES

The following quality parameters of the prepared fruit wines were analysed

3.2.1. Chemical properties

Chemical properties of wine *viz.*, Total soluble solids (TSS), titratableacidity (%), sugar content ($g100g^{-1}$), antioxidant activity (%), polyphenol content (mgg^{-1}) and alcohol content (%) were analysed.

3.2.1.a TSS(^0B)

Total Soluble Solids (TSS) of wine was recorded using hand refractometer (0-32^0 B) and expressed in ^{0} Brix.

3.2.1.b. Acidity (%)

The method described by Ranganna (1986) was followed to measure titratable acidity. The titratable acidity was expressed in terms of per cent citric acid equivalent using following formula:

$$\text{Acidity} = \frac{\text{Titre value} \times \text{Normality of NaOH } (0.1N) \times \text{Volume made up } (100mL) \times \text{Equivalent weight of citric acid } (0.064) \times 100}{\text{Volume of aliquot } (25\,Ml) \times \text{Weight / Volume of the sample } (5g)}$$

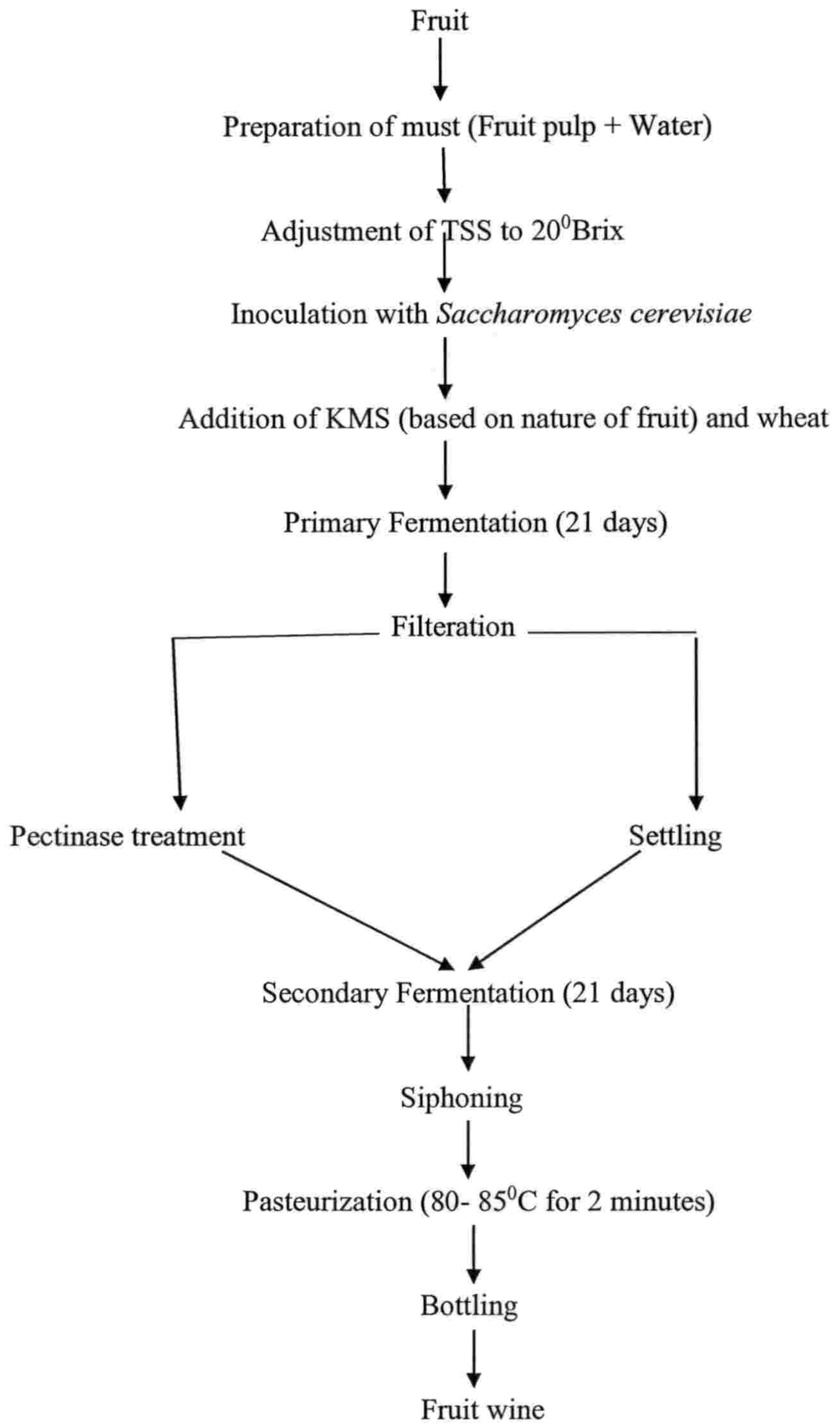


Fig 1. Flow chart showing preparation of fruit wine.

3.2.1.c. Sugar content (g100g-1)

Reducing Sugar(g100g-1)

The titrimetric method of Lane and Eynon as described by Ranganna (1986) was adopted for the estimation of reducing sugar.

$$\text{Reducing sugar} = \frac{Glucose\ Eq.(0.05) \times Total\ volume\ made\ up\ (mL) \times 100}{Titre\ value\ (mL) \times Weight\ of\ the\ sample(g)}$$

Total Sugar(g100g-1)

The total sugar content was expessed as percent in terms of invert sugar according to the following formula (Ranganna, 1986).

$$\text{Total sugar} = \frac{Glucose\ Eq.(0.05) \times Total\ volume\ made\ up\ (mL) \times volume\ made\ up\ after\ inversion \times 100}{Titre\ value \times Weight\ of\ pulp\ taken(g) \times Aliqout\ taken\ for\ inversion\ (mL)}$$

3.2.1.d. Alcohol Content (%)

Total alcohol content of the wine was estimated using the method described by Sadasivam and Manickam (1992).

Wine sample (4ml) was made upto 100 ml with distilled water and 5 ml of the diluted sample was transferred to a screwed conical flask. 10 ml of 0.05 M potassium chromate and 20 ml 50% sulphuric acid solution were added slowly to the flask.

Flasks were capped loosely and heated in a water bath at 50^0C for 60 minutes. 10 ml of 0.5 M Potassium Iodide was added to the flask after removing from the water bath and the contents were titrated with 0.1 M Sodium Thiosulphate solution. When the brown colour of the solution got a green tinge, 1ml of 1% freshly prepared starch indicator was added, which was prepared in boiling water. The addition of Sodium Thiosulphate was continued till the solution got a clear blue-green colour which was the end point of titration. The alcohol content of wine was calculated using the following formula:

Number of moles in V mL of 0.1 M Sodium Thiosulphate= $\frac{24.818 \times V}{1000}$ (n moles)

Where,

V is the burette reading.

Extra moles of Dichromate spent by thiosulphate = n/6

Number of moles of Dichromate reacted to oxidise alcohol (n_1) = number of moles added – moles spent by thiosulphate.

Number of moles of alcohol = 3 x n_1

Volume of alcohol in 5 ml of the diluted sample = (3 n_1x 58.6)

Volume of alcohol in 100 ml diluted sample = [(3 n_1 x 58.6) x 50]

Percentage of alcohol present in 10 ml of original sample = [(3 n_1 x 58.6) x 50 x 10]

3.2.1.e. Polyphenol content (mg g^{-1})

Polyphenol content of the wine was estimated by the method described by Sadashivam and Manickam (1992).

Wine sample (1 ml) was mixed with 10 times volume of 80% ethanol and the homogenate was centrifuged at 10,000 rpm for 20 minutes. The supernatant was evaporated to dryness and the residue was dissolved in 5 ml of distilled water. Pipetted out 0.5 ml of the aliqout in test tubes, made up the volume to 3 ml with distilled water and 0.5 ml Folin-Ciocalteu reagent was added. Na_2CO_3, 20 percent (2ml) was added to the test tubes after 3 minutes and mixed thoroughly. The test tubes were placed in boiling water for one minute, cooled and the absorbance was measured at 765 nm against the reagent blank. Standard curve was prepared using different concentrations of gallic acid and phenol content of the test sample was expressed as mg phenols g^{-1} of winesample.

3.2.1.f. Antioxidant Activity (%)

Antioxidant activity of wine was determined using 2, 2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay. The scavenging effect on DPPH free radical was measured according to the procedure described by Sharma and Bhat (2009)

Wine sample (1ml) was added to 2.0 ml 0.1mM DPPH solution, mixed thoroughly and left for 30 minutes at room temperature. The absorbance was read at 517 nm. Scavenging effect was expressed as percent inhibition of DPPH as shown in the following equation:

$$\% \text{ inhibition of DPPH} = \frac{\{A\ blank - A\ sample\} \times 100}{A\ blank}$$

Where,

A_{blank} – Absorbance of DPPH solution without sample, read against ethanol blank.

A_{sample}- Absorbance of the test sample after 30 min.

3.2.2. Sensory Attributes

Wines prepared from different fruits were subjected to evaluation for sensory characteristics *viz.,* appearance, colour, flavour, texture, odour, taste and after taste by 10-member semi trained panel comprising of potential customers and occasional wine drinkers from Research scholars and Faculty members of College of Agriculture, Vellayani. The semi trained panel were asked to score quality parameters of the coded fruit wine samples using 9-point Hedonic scale given by Amerine *et al*., (1967) in the order of preference as shown below.

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

Score card for the sensory analysis is shown as Appendix I

3.3. Selection of the best fruit wine

The best wine from each fruit was selected based on the physical, chemical and sensory quality parameters.

3.4. Storage studies

The best wine selected from each fruit, based on physical, chemical and sensory quality parameters,was stored under ambient condition for a period of three months in the following two different packaging materials (Plate 2.) for analyzing the storage stability.

S_1- Amber coloured glass bottles

S_2- Plain glass bottles.

Packaging materials	-2
Replication	-7
Design	- CRD

The following quality parameters were recorded initially at the time of storage and during alternate months for a period of three months.

3.4.1. Quality analysis

3.4.1.a. Alcohol content (%)

Alcohol contentof the best wine was recorded as in3.2.1.d.

3.4.1.b. Polyphenol content

Polyphenol content of the best wine was recorded as in 3.2.1.e.

3.4.1.c. Microbial load

The quantitative assay of the micro flora in stored samples was carried out by serial dilution spread plate techniques. Nutrient agar and acetobacter agar medium were used for the enumeration of bacterial population of fruit wines.

$$\text{No. of colony forming units Per gram of samples} = \frac{\text{Total no. of colony formed x dilution factor}}{\text{Aliquot taken}}$$

2(a) Amber Container

2(b) Plain Glass Container

Plate.2 (a,b). Containers selected for storage studies

3.5. Statistical Analysis

The data generated from the experiments were statistically analysed using Completely Randomised Design (CRD). The sensory score of different wines were statistically analysed using Kruskall-Wallis test (chi square value) and ranked (Shamrez *et al.,* 2013).

Results

4. RESULTS

The experiment entitled "Standardization of quality wine production from selected underexploited fruits" was conducted, data analysed and the results are presented under the following headings.

1. Fruit wine preparation
2. Quality analysis of fruit wines
3. Selection of the best fruit wine
4. Storage potential of fruit wines

4. 1. FRUIT WINE PREPARATION

Fruit wines were prepared from four different underexploited fruits viz., carambola, papaya, jamun and rose apple independently by varying three process parameters viz., fruit: water ratio, yeast concentration and clarification methods. Fruit: water ratio was tried at 1:0.75, 1:1 and 1:2; yeast concentration at 0.5, 0.75 and 1% and clarification by pectinase enzyme and by settling, thus forming 18 different fruit wines in each fruit.

4.2. QUALITY ANALYSIS OF FRUIT WINES

4. 2. 1. Carambola

4. 2. 1. 1. Chemical evaluation

The chemical quality parameters of the carambola wines were recorded and shown in Tables 1-5.

1. TSS (^{0} Brix)

There was no significant difference between the TSS content of different carambola wines (Table 1.). However the highest TSS (4.6^0 Brix) was recorded in wine produced with 1:2 fruit: water ratio, 0.75% yeast and clarified using pectinase and the least TSS (2.8^0 Brix) was recorded in wine produced using 1:0.75 fruit: water ratio, 1% yeast and clarified using pectinase.

2. Acidity (% titrable acidity as citric acid)

No significant difference was observed between the acidity content of different carambola wines (Table 2.). However, the lowest acidity (0.3%) was recorded in the wines prepared using fruit: water ratio of 1:0.75 and 1:1 and 1% yeast irrespective of clarification methods.

3. Sugar content (g 100g-1)

Sugars (Total sugars and reducing sugars) were absent or not detectable in all the carambola wines.

4. Alcohol content (%)

Alcohol content was highest (12.3%) when the wine was prepared using 1:2 fruit: water ratio, 1% yeast and clarified using pectinase (Table 3.). This wine was on par with the wine which was produced in the same manner, but with 0.5 % yeast (12.0 %) and the one clarified by settling (11.6%). Wines which were produced using 1:1 fruit: water ratio and 1% yeast had recorded least alcohol (7.2%) content irrespective of clarification method. This was on par with all the wines produced using 1:1 fruit: water ratio except the one, to which 0.5% yeast was added and clarified by pectinase (8.2).

5. Total phenol (mg g^{-1})

There was significant difference between the polyphenol content of different fruit wines (Table 4.) Wines recorded the least polyphenol (169.40 mgg^{-1}) content when fruit: water ratio was maintained at 1:2 ratio, yeast concentration of 0.5% and clarification done by pectinase. This wine was on par with the wine which was prepared in the same manner, but with 0.75% yeast (183.63 mgg^{-1}). Polyphenol content was maximum (508.58 mgg^{-1}) when wine was produced with 1:0.75 fruit: water ratio, 0.75% yeast and clarified by settling. This was on par with the wine produced in the same manner but with 0.5% yeast (482.97 mgg^{-1}) and the wine produced with the same yeast content and same manner of clarification but with 1:1 fruit: water ratio (488.25 mgg^{-1}).

Table 1. Effect of fruit water ratio, yeast concentration and clarification on TSS of carambola wines

TSS(^{0} Brix)						
Fruit water ratio (R)	Yeast concentration (C)					
	C_1 (0.5 %)		C_2 (0.75 %)		C_3 (1%)	
	Cl_1 (Pectinase)	Cl_2 (Settling)	Cl_1 (Pectinase)	Cl_2 (Settling)	Cl_1 (Pectinase)	Cl_2 (Settling)
R_1(1:0.75)	4.0	4.0	4.0	4.4	2.8	3.0
R_2 (1:1)	4.4	4.0	4.2	4.2	4.0	3.6
R_3 (1:2)	4.4	4.4	4.6	4.4	4.2	4.4
CD (R x C x Cl)	NS					

Table 2. Effect of fruit water ratio, yeast concentration and clarification on acidity of carambola wines

Acidity (%)						
Fruit water ratio (R)	Yeast concentration (C)					
	C_1 (0.5 %)		C_2 (0.75 %)		C_3 (1%)	
	Cl_1 (Pectinase)	Cl_2 (Settling)	Cl_1 (Pectinase)	Cl_2 (Settling)	Cl_1 (Pectinase)	Cl_2 (Settling)
R_1(1:0.75)	0.5	0.5	0.4	0.4	0.3	0.3
R_2 (1:1)	0.7	0.6	0.5	0.6	0.3	0.3
R_3 (1:2)	0.4	0.4	0.5	0.6	0.5	0.4
CD (R x C x Cl)	NS					

Table 3. Effect of fruit water ratio, yeast concentration and clarification on alcohol content of carambola wines

Alcohol content (%)						
Fruit water ratio (R)	Yeast concentration (C)					
	C_1 (0.5 %)		C_2 (0.75 %)		C_3 (1%)	
	Cl_1 (Pectinase)	Cl_2 (Settling)	Cl_1 (Pectinase)	Cl_2 (Settling)	Cl_1 (Pectinase)	Cl_2 (Settling)
R_1(1:0.75)	9.6	9.3	9.1	8.7	8.2	8.4
R_2 (1:1)	8.2	7.8	7.9	7.8	7.2	7.2
R_3 (1:2)	12.0	10.7	8.9	8.8	12.3	11.6
CD (R x C x Cl)	0.9					

55

6. Antioxidant activity (%)

Antioxidant activity was highest (82.4%) when the wine was prepared with 1: 0.75 fruit: water ratio, 0.75% yeast and clarified using pectinase (Table 5.). This was followed by the wine which was prepared using 1:2 fruit: water ratio, 0.75% yeast and pectinase as clarifying agent (64.9%), which was on par with the wine produced in the same manner, but clarified by settling (61.9%).

4. 2. 1. 2. Sensory evaluation

Different carambola wines were analysed for various sensory attributes using 9 point hedonic scale to assess their acceptance (Table 6).

1. ***Appearance***

The carambola wine prepared using 1:0.75 fruit: water ratio, 1% yeast and clarified by settling had the highest mean score (8.5) for appearance, which was followed by the wines prepared using 1:2 fruit: water ratio, 0.75% yeast and clarified by settling (7.8) and pectinase (7.6). The wine prepared using 1:0.75 fruit: water ratio, 0.5% yeast and clarified by pectinase had the least mean score for appearance(1.6).

2. ***Colour***

The highest mean score for colour (8.4) was recorded in wine prepared using 1:0.75 fruit: water ratio, 1% yeast and clarified by settling, followed by the wines prepared using 1:2 fruit: water ratio, 0.75% yeast and clarified by settling (7.1) and pectinase (6.8).The lowest mean score for colour (1.9) was obtained for the wine prepared using 1:0.75 fruit: water ratio, 0.5% yeast and clarified by pectinase.

3. ***Flavour***

The highest mean score for flavour (6.5) was obtained for the wine prepared using 1:2 fruit: water ratio, 0.75% yeast and clarified by settling

Table 4. Effect of fruit water ratio, yeast concentration and clarification on polyphenol content of carambola wines

Polyphenol content(mgg^{-1})						
Fruit water ratio (R)	Yeast concentration (C)					
	C_1 (0.5 %)		C_2 (0.75 %)		C_3 (1%)	
	Cl_1 (Pectinase)	Cl_2 (Settling)	Cl_1 (Pectinase)	Cl_2 (Settling)	Cl_1 (Pectinase)	Cl_2 (Settling)
R_1(1:0.75)	467.35	482.97	413.89	508.58	319.31	245.68
R_2 (1:1)	364.57	399.57	437.39	488.25	340.15	344.05
R_3 (1:2)	169.40	424.59	183.63	261.04	289.47	372.50
CD (R x C x Cl)	36.14					

Table 5. Effect of fruit water ratio, yeast concentration and clarification on antioxidant activity of carambola wines

Antioxidant activity (%)						
Fruit water ratio (R)	Yeast concentration (C)					
	C_1 (0.5 %)		C_2 (0.75 %)		C_3 (1%)	
	Cl_1 (Pectinase)	Cl_2 (Settling)	Cl_1 (Pectinase)	Cl_2 (Settling)	Cl_1 (Pectinase)	Cl_2 (Settling)
R_1(1:0.75)	11.9	8.6	82.4	60.2	51.6	21.5
R_2 (1:1)	25.8	17.2	20.2	25.2	8.6	5.6
R_3 (1:2)	32.4	38.4	64.9	61.9	32.4	43.4
CD (R x C x Cl)	3.7					

Table 6. Effect of fruit water ratio, yeast concentration and clarification on sensory quality of carambola wines

Treatments	Appearance		Colour		Flavour		Texture		Taste		After taste	
	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank
T_1 -1:0.75 F-W + 0.5% Yeast + Pectinase	1.6	29.22	1.9	35.13	2.6	60.18	2.4	50.68	1.9	47.45	2.3	61.45
T_2 -1:0.75 F-W + 0.5% Yeast + Settling	3.1	53.22	3.9	73.09	3.3	79.63	2.6	52.22	2.2	54.59	2.7	71.04
T_3 -1:0.75 F-W + 0.75% Yeast + Pectinase	5.9	108.59	3.7	67.59	2.2	53.18	3.1	69.40	2.1	53.36	2.7	72.13
T_4 -1:0.75 F-W + 0.75% Yeast + Settling	3.5	61.18	4.8	93.45	3.2	75.59	3.0	64.81	3.5	88.50	3.2	81.86
T_5 -1:0.75 F-W + 1% Yeast + Pectinase	5.1	93.00	5.1	98.54	2.5	58.95	3.2	68.95	2.6	66.86	2.8	73.54
T_6 -1:0.75 F-W + 1% Yeast + Settling	8.5	166.54	8.4	164.81	3.9	92.22	4.2	102.04	2.7	68.81	2.8	71.86
T_7 -1:1 F-W + 0.5% Yeast + Pectinase	6.9	129.95	6.7	133.86	4.5	101.04	4.2	106.54	4.1	102.00	3.0	78.68
T_8 -1:1 F-W + 0.5% Yeast + Settling	5.8	106.63	7.2	143.72	4.4	104.40	5.1	131.04	3.3	85.50	2.7	71.86
T_9 -1:1 F-W + 0.75% Yeast + Pectinase	6.9	129.95	5.7	112.63	2.8	67.18	3.6	82.31	3.2	82.04	2.9	76.31
T_{10} -1:1 F-W + 0.75% Yeast + Settling	4.1	72.59	3.8	69.77	4.1	96.77	4.7	120.95	3.9	106.09	4.1	109.86
T_{11} -1:1 F-W + 1% Yeast + Pectinase	5.3	96.59	4.9	94.50	2.8	67.95	3.9	94.68	3.7	99.27	4.0	106.95
T_{12} -1:1 F-W + 1% Yeast + Settling	7.5	142.59	6.7	130.09	4.3	102.81	4.3	105.22	4.3	112.54	3.7	99.31
T_{13} -1:2 F-W + 0.5% Yeast + Pectinase	3.5	61.40	2.8	48.13	5.8	134.22	4.6	116.27	4.9	122.18	4.2	111.68
T_{14} -1:2 F-W + 0.5% Yeast + Settling	3.9	69.59	4.8	91.86	6.0	138.45	3.6	85.63	5.6	138.50	4.9	128.77
T_{15} -1:2 F-W + 0.75% Yeast + Pectinase	7.6	148.68	6.8	150.09	6.4	148.22	5.2	132.77	5.5	139.63	5.7	149.59
T_{16} -1:2 F-W + 0.75% Yeast + Settling	7.8	149.68	7.1	152.13	6.5	148.77	5.1	130.27	5.5	137.45	5.2	135.59
T_{17} -1:2 F-W + 1% Yeast + Pectinase	3.2	57.72	3.1	57.27	5.4	124.59	5.1	131.95	6.0	148.50	5.6	142.04
T_{18} -1:2 F-W + 1% Yeast + Settling	5.0	93.09	3.7	67.27	6.3	135.77	5.1	132.18	5.4	136.68	5.8	151.40
K value	96.68		91.44		61.18		52.02		63.78		53.80	
χ^2	27.587		27.587		27.587		27.587		27.587		27.587	

followed by wine prepared using the same method, but clarified by pectinase (6.4). The lowest mean score (2.2) was recorded for wine prepared using 1:0.75 fruit: water ratio, 0.75% yeast and clarified by pectinase.

4. Texture

The highest mean score for texture (5.2) was obtained for the wine prepared using 1:2 fruit: water ratio, 0.75% yeast and clarified by pectinase. The lowest mean score (2.4) for texture was obtained for the wine prepared from 1:0.75 fruit: water ratio, 0.5% yeast and clarified by pectinase.

5. Taste

The highest mean score for taste (6.0) was recorded for the wine prepared using 1:2 fruit: water ratio, 1% yeast and clarified by pectinase, which was followed by the wine prepared using 1:2 fruit: water ratio, 0.75% yeast irrespective of clarification methods (5.5). The least preferred wine (1.9) in terms of taste was the one prepared using 1:0.75 fruit: water ratio, 0.5% yeast and clarified by pectinase.

6. Aftertaste

The wine prepared from 1:2 fruit: water ratio, 1% yeast and clarified by settling had highest score for aftertaste (5.8) which was closely followed by the wine prepared using 1:2 fruit: water ratio, 0.75% yeast and clarified by pectinase (5.7). The wine with least score for aftertaste (2.3) was the one prepared using 1:0.75 fruit: water ratio, 0.5% yeast and clarified by pectinase.

4. 2. 2. Papaya

4. 2. 2. 1. Chemical evaluation

The chemical quality parameters of different papaya wines were evaluated and shown in Tables 7-11.

1. TSS (^{0} Brix)

There was no significant difference between the TSS content of different papaya wines (Table 7.). However highest TSS value (4.4 ^{0} Brix) was recorded in wines produced with 1:1 fruit: water ratio and 0.5% yeast irrespective of clarification methods. Least TSS (3.0^0 Brix) was recorded in wine produced with 1:2 fruit: water ratio and 1% yeast irrespective of clarification methods.

2. Acidity (% titrable acidity as citric acid)

There was significant difference between the acidity content of papaya wines (Table 8.). The lowest acidity value (0.25%) was recorded in the wines prepared using 1:2 fruit: water ratio, 0.5% yeast and clarified using pectinase and in wine produced using 1:0.75 fruit: water ratio, 1% yeast and clarified by settling. The wines produced by the same methods, but varying in clarification also had similar low acidity (0.28%) content. The highest acidity value (0.65%) was found in the wine produced with 1:1 fruit: water ratio, 0.5% yeast and clarified by settling. This was on par with all other papaya wines produced using fruit: water ratio of 1:1, except the one to which 1% yeast was added.

3. Sugar content (g100g-1)

Sugar (Total sugars and reducing sugars) was absent in all the papaya wines.

4. Alcohol content (%)

Alcohol content was highest (17.28%) when the papaya wine was produced using 1:1 fruit: water ratio, 0.75% yeast and clarified by settling which was on par with wine produced in the same manner but clarified using pectinase (16.36%) (Table 9.). The wines produced using 1:2 fruit: water ratio with 1% yeast and 1:0.75 fruit: water ratio with 0.5% yeast both clarified using pectinase had the least alcohol content (6.15%). This was on par with wines produced using 1:1 fruit: water ratio, 0.75% yeast, clarified by pectinase (7.03%) and settling

Table 7. Effect of fruit water ratio, yeast concentration and clarification on TSS of papaya wines

TSS(^{0} Brix)						
Fruit water ratio (R)	Yeast concentration (C)					
	C_1 (0.5 %)		C_2 (0.75 %)		C_3 (1%)	
	Cl_1 (Pectinase)	Cl_2 (Settling)	Cl_1 (Pectinase)	Cl_2 (Settling)	Cl_1 (Pectinase)	Cl_2 (Settling)
R_1(1:0.75)	4.0	4.0	4.2	4.2	4.0	4.0
R_2 (1:1)	4.4	4.4	4.2	4.2	4.0	4.0
R_3 (1:2)	3.8	3.8	3.2	3.2	3.0	3.0
CD (R x C x Cl)	NS					

Table 8. Effect of fruit water ratio, yeast concentration and clarification on acidity of papaya wines

Acidity (%)						
Fruit water ratio (R)	Yeast concentration (C)					
	C_1 (0.5 %)		C_2 (0.75 %)		C_3 (1%)	
	Cl_1 (Pectinase)	Cl_2 (Settling)	Cl_1 (Pectinase)	Cl_2 (Settling)	Cl_1 (Pectinase)	Cl_2 (Settling)
R_1(1:0.75)	0.38	0.46	0.41	0.41	0.28	0.25
R_2 (1:1)	0.64	0.65	0.61	0.59	0.36	0.38
R_3 (1:2)	0.25	0.28	0.54	0.56	0.46	0.46
CD (R x C x Cl)	0.07					

Table 9. Effect of fruit water ratio, yeast concentration and clarification on alcohol content of papaya wines

Alcohol content (%)						
Fruit water ratio (R)	Yeast concentration (C)					
	C_1 (0.5 %)		C_2 (0.75 %)		C_3 (1%)	
	Cl_1 (Pectinase)	Cl_2 (Settling)	Cl_1 (Pectinase)	Cl_2 (Settling)	Cl_1 (Pectinase)	Cl_2 (Settling)
R_1(1:0.75)	6.15	9.37	11.72	11.13	12.59	13.73
R_2 (1:1)	7.61	7.90	16.36	17.28	13.76	14.06
R_3 (1:2)	7.32	7.61	7.03	6.73	6.15	6.44
CD (R x C x Cl)	1.16					

(6.73%). Wines produced using 1:2 fruit: water ratio, with 1% yeast and clarified by settling also had similer least (6.44%) alcohol content.

5. *Polyphenol content (mgg^{-1})*

Polyphenol content was least (170.12 mgg^{-1}) when the wine was produced using 1:1 fruit: water ratio, with 0.75% yeast and clarified by pectinase (Table 10.). Polyphenol content was maximum (339.53 mgg^{-1}) when wine was produced using 1:1 fruit: water ratio, 0.5% yeast and clarified by settling.

6. *Antioxidant activity (%)*

Antioxidant activity was highest (79.46%) for the wine prepared using 1:2 fruit: water ratio, 1% yeast and clarified using pectinase. This was closely followed by the wine produced in the same manner but clarified by settling (76.15%) (Table 11.). The least antioxidant activity (14.20%) was observed in the wine prepared using 1:1 fruit: water ratio, 0.5% yeast and clarified by settling which was on par with the wine prepared in the same manner but clarified using pectinase (16.50%).

4. 2. 2. 2. **Sensory evaluation**

Different papaya wines were analysed for various sensory attributes using 9 point hedonic scale to assess their acceptance (Table 12).

1. *Appearance*

Papaya wine prepared using 1:2 fruit: water ratio, 0.75% yeast and clarified by pectinase had the highest mean score (7.1) for appearance, which was followed by the wine prepared using the same method, but clarified by settling (6.6) and the wine prepared using 1:2 fruit: water ratio, 1% yeast and clarified by pectinase (5.4). The wine prepared using 1:0.75 fruit: water ratio, 0.5% yeast and clarified by pectinase had the least mean score (2.1) for appearance.

Table 10. Effect of fruit water ratio, yeast concentration and clarification on polyphenol content of papaya wines

Polyphenol content(mgg^{-1})						
Fruit water ratio (R)	Yeast concentration (C)					
	C_1 (0.5 %)		C_2 (0.75 %)		C_3 (1%)	
	Cl_1 (Pectinase)	Cl_2 (Settling)	Cl_1 (Pectinase)	Cl_2 (Settling)	Cl_1 (Pectinase)	Cl_2 (Settling)
R_1(1:0.75)	239.30	222.00	252.67	281.75	299.05	310.05
R_2 (1:1)	315.56	339.53	170.12	181.12	229.08	244.02
R_3 (1:2)	252.67	277.03	181.91	192.13	201.57	187.41
CD (R x C x Cl)	8.23					

Table 11. Effect of fruit water ratio, yeast concentration and clarification on antioxidant activity of papaya wines

Antioxidant activity (%)						
Fruit water ratio (R)	Yeast concentration (C)					
	C_1 (0.5 %)		C_2 (0.75 %)		C_3 (1%)	
	Cl_1 (Pectinase)	Cl_2 (Settling)	Cl_1 (Pectinase)	Cl_2 (Settling)	Cl_1 (Pectinase)	Cl_2 (Settling)
R_1(1:0.75)	19.86	27.47	34.43	39.73	38.40	41.70
R_2 (1:1)	16.50	14.20	17.80	19.86	47.01	51.65
R_3 (1:2)	56.95	60.26	66.88	64.89	79.46	76.15
CD (R x C x Cl)	3.44					

63

2. *Colour*

The highest mean score for colour (7.9) was recorded in wine prepared using 1:2 fruit: water ratio, 0.75% yeast and clarified by pectinase, followed by the wine prepared using the same method, but clarified by settling (7.4). The wine prepared using 1:2 fruit: water ratio, 1% yeast and clarified by pectinase and wine produced using 1:1 fruit: water ratio, 0.5% yeast and clarified by settling also had mean score of 7.4 for colour. The lowest mean score for colour (1.5) was obtained for the wine prepared using 1:0.75 fruit: water ratio, 0.5% yeast and clarified by pectinase.

3. *Flavour*

The highest mean score for flavour (8.2) was obtained for the wine prepared using 1:2 fruit: water ratio, 0.75% yeast and clarified by pectinase followed by wine prepared using the same method, but clarified by settling (7.5). The lowest mean score (1.4) was recorded for wine prepared using 1:0.75 fruit: water ratio, 0.5% yeast and clarified by pectinase.

4. *Texture*

The highest mean score for texture (8.2) was obtained for the wine prepared using 1:2 fruit: water ratio, 0.75% yeast and clarified by settling followed by the wine prepared using the same method, but clarified by pectinase (7.9) and the wine prepared using 1:2 fruit: water ratio, 1% yeast and clarified using pectinase (6.6). The lowest mean score (1.7) for texture was obtained for the wine prepared from 1:0.75 fruit: water ratio, 0.5% yeast and clarified by pectinase.

5. *Taste*

The highest mean score for taste (5.8) was recorded for the wine prepared using 1:2 fruit: water ratio, 1% yeast and clarified by settling, which was followed by the wine prepared using the same method but clarified using pectinase (5.7).

Table 12. Effect of fruit water ratio, yeast concentration and clarification on sensory quality of papaya wines

Treatments	Appearance		Colour		Flavour		Texture		Taste		After taste	
	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank
T_1 -1:0.75 F-W + 0.5% Yeast + Pectinase	2.1	15.70	1.5	9.50	1.4	16.9	1.7	20.45	2.3	61.45	1.9	47.45
T_2 -1:0.75 F-W + 0.5% Yeast + Settling	2.7	30.25	2.5	26.50	3.1	73.05	2.3	36.70	2.7	71.04	2.2	54.59
T_3 -1:0.75 F-W + 0.75% Yeast + Pectinase	4.9	94.80	3.7	57.00	2.5	54.90	3.7	80.30	2.7	72.13	2.1	53.36
T_4 -1:0.75 F-W + 0.75% Yeast + Settling	4.7	87.90	4.6	81.80	2.4	45.80	3.8	83.90	3.2	81.86	3.5	88.50
T_5 -1:0.75 F-W + 1% Yeast + Pectinase	4.4	79.30	4.3	73.50	3.0	71.15	4.3	99.60	2.8	73.54	2.6	66.86
T_6 -1:0.75 F-W + 1% Yeast + Settling	5.3	106.35	6.2	122.10	3.0	69.35	4.4	102.35	2.8	71.86	2.7	68.81
T_7 -1:1 F-W + 0.5% Yeast + Pectinase	5.1	97.65	6.9	139.50	3.5	88.75	4.5	98.55	3.0	78.68	4.1	102.00
T_8 -1:1 F-W + 0.5% Yeast + Settling	4.4	80.80	7.4	152.10	3.5	85.05	2.9	54.35	2.7	71.86	3.3	85.50
T_9 -1:1 F-W + 0.75% Yeast + Pectinase	5.1	97.90	5.1	94.00	3.4	84.45	3.5	74.70	2.9	76.31	3.2	82.04
T_{10} -1:1 F-W + 0.75% Yeast + Settling	3.0	38.10	3.6	52.50	4.8	132.70	3.3	66.95	4.1	109.86	3.9	106.09
T_{11} -1:1 F-W + 1% Yeast + Pectinase	5.3	106.80	4.5	78.90	2.4	49.40	2.6	45.05	4.0	106.95	3.7	99.27
T_{12} -1:1 F-W + 1% Yeast + Settling	4.8	91.00	4.3	74.10	3.1	73.65	3.8	83.70	3.7	99.31	4.3	112.54
T_{13} -1:2 F-W + 0.5% Yeast + Pectinase	3.7	56.10	3.1	41.50	2.9	66.40	3.1	61.35	4.2	111.68	4.9	122.18
T_{14} -1:2 F-W + 0.5% Yeast + Settling	3.0	35.65	3.4	50.50	4.6	115.25	5.7	137.50	4.9	128.77	5.6	138.50
T_{15} -1:2 F-W + 0.75% Yeast + Pectinase	7.1	150.35	7.9	160.35	8.2	170.20	7.9	166.30	5.6	139.04	5.4	136.68
T_{16} -1:2 F-W + 0.75% Yeast + Settling	6.6	139.45	7.4	152.10	7.5	167.95	8.2	169.05	5.2	135.59	5.5	138.45
T_{17} -1:2 F-W + 1% Yeast + Pectinase	5.4	115.75	7.4	150.75	5.4	141.25	6.6	148.60	5.7	149.59	6.0	148.50
T_{18} -1:2 F-W + 1% Yeast + Settling	4.5	82.15	5.8	112.30	4.6	122.80	4.4	99.60	5.8	151.40	5.5	139.63
K value	129.33		142.71		117.27		116.83		53.80		63.78	
χ^2	27.587		27.587		27.587		27.587		27.587		27.587	

The least preferred wine (2.3) in terms of taste was the one prepared using 1:0.75 fruit: water ratio, 0.5% yeast and clarified by pectinase.

6. Aftertaste

The wine prepared from 1:2 fruit: water ratio, 1% yeast and clarified by pectinase had highest score for aftertaste (6.0) which was followed by the wine prepared using 1:2 fruit: water ratio, 0.5% yeast and clarified by settling (5.6). The wine with least score for aftertaste was the one prepared using 1:0.75 fruit: water ratio, 0.5% yeast and clarified by pectinase (1.9).

4.2. 3. Jamun

4. 2. 3. 1. Chemical evaluation

The chemical quality parameters of the jamun wines were recorded and shown in Tables 13-17.

1. TSS (^{0} Brix)

There was no significant difference between the TSS content of different jamun wines (Table 13.). TSS content of wines varied from 2.8 - 5.0 ^{0} Brix.

2. Acidity (% titrable acidity as citric acid)

The lowest acidity (0.69%) was recorded in the wines produced using fruit: water ratio of 1:1, 0.75% yeast and clarified by settling (Table 14.). The wine produced using 1:0.75 fruit: water ratio, 0.75% yeast and clarified using pectinase showed the highest acidity (5.42%).

3. Sugar content (g100g-1)

Sugar (Total sugars and reducing sugars) was absent in all the jamun wines, produced

Table 13. Effect of fruit water ratio, yeast concentration and clarification on TSS of jamun wines

TSS(^{0} Brix)						
Fruit water ratio (R)	Yeast concentration (C)					
	C_1 (0.5 %)		C_2 (0.75 %)		C_3 (1%)	
	Cl_1 (Pectinase)	Cl_2 (Settling)	Cl_1 (Pectinase)	Cl_2 (Settling)	Cl_1 (Pectinase)	Cl_2 (Settling)
R_1(1:0.75)	4.2	4.0	3.8	3.4	2.8	4.6
R_2 (1:1)	5.0	4.8	4.2	4.6	5.0	5.0
R_3 (1:2)	5.0	4.8	4.8	4.6	4.4	4.0
CD (R x C x Cl)	NS					

Table 14. Effect of fruit water ratio, yeast concentration and clarification on acidity of jamun wines

Acidity (%)						
Fruit water ratio (R)	Yeast concentration (C)					
	C_1 (0.5 %)		C_2 (0.75 %)		C_3 (1%)	
	Cl_1 (Pectinase)	Cl_2 (Settling)	Cl_1 (Pectinase)	Cl_2 (Settling)	Cl_1 (Pectinase)	Cl_2 (Settling)
R_1(1:0.75)	2.40	4.50	5.42	2.35	1.10	3.94
R_2 (1:1)	2.71	2.46	0.84	0.69	3.09	4.15
R_3 (1:2)	0.97	1.43	1.48	1.04	3.64	2.53
CD (R x C x Cl)	0.09					

Table 15. Effect of fruit water ratio, yeast concentration and clarification on alcohol content of jamun wines

Alcohol content (%)						
Fruit water ratio (R)	Yeast concentration (C)					
	C_1 (0.5 %)		C_2 (0.75 %)		C_3 (1%)	
	Cl_1 (Pectinase)	Cl_2 (Settling)	Cl_1 (Pectinase)	Cl_2 (Settling)	Cl_1 (Pectinase)	Cl_2 (Settling)
R_1(1:0.75)	16.36	24.00	17.00	19.90	20.51	11.13
R_2 (1:1)	12.88	11.42	11.13	7.61	22.26	11.13
R_3 (1:2)	7.32	9.38	8.20	7.02	6.44	7.32
CD (R x C x Cl)	0.61					

67

4. Alcohol content (%)

There was significant difference between the alcohol content of different jamun wines (Table 15.). Alcohol content was highest (24 %) when the wine was produced using 1:0.75 fruit: water ratio, 0.5% yeast and clarified by settling. This was closely followed by the wine prepared using 1:1 fruit: water ratio, 1% yeast and clarified using pectinase (22.26%). Least alcohol content (6.44%) was recorded by the wine prepared using 1:2 fruit: water ratio, 1% yeast and clarified using pectinase.

5. Polyphenol content (mgg^{-1})

The least polyphenol (5.81mgg^{-1}) content was recorded when fruit: water ratio was maintained at 1:0.75 ratio, yeast concentration of 0.75% and clarification done by pectinase (Table 16.). Polyphenol content was maximum (37.26mgg^{-1}) when wine was produced with 1:0.75 fruit: water ratio, 0.5% yeast and clarified using pectinase.

6. Antioxidant activity (%)

Highest antioxidant activity (24.83%) was observed when the wine was prepared with 1:0.75 fruit: water ratio, 0.75% yeast and clarified using pectinase (Table 17.). This was on par with wines prepared in the same manner but clarified by settling (23.5%) and the wines prepared with the same fruit: water ratio but with 1% yeast and clarified by settling (23.83). The wine prepared using 1:1 fruit: water ratio, 1% yeast and clarified using pectinase also had similar high antioxidant activity (24.5%). The lowest antioxidant activity (11.92%) was recorded in the wine prepared using 1:2 fruit: water ratio, 0.5% yeast and clarified using pectinase which was on par with the wine produced in the same manner but clarified by settling (12.9%) and also the wines prepared using the same fruit: water ratio but with 0.75% yeast , irrespective of clarification methods.

Table 16. Effect of fruit water ratio, yeast concentration and clarification on polyphenol content of jamun wines

Polyphenol content(mgg^{-1})						
Fruit water ratio (R)	Yeast concentration (C)					
	C_1 (0.5 %)		C_2 (0.75 %)		C_3 (1%)	
	Cl_1 (Pectinase)	Cl_2 (Settling)	Cl_1 (Pectinase)	Cl_2 (Settling)	Cl_1 (Pectinase)	Cl_2 (Settling)
R_1(1:0.75)	37.26	21.53	5.81	13.67	10.53	8.96
R_2 (1:1)	11.31	14.46	17.60	8.96	28.61	27.04
R_3 (1:2)	13.10	7.38	12.10	10.04	18.52	20.75
CD (R x C x Cl)	7.84					

Table 17. Effect of fruit water ratio, yeast concentration and clarification on antioxidant activity of jamun wines

Antioxidant activity (%)						
Fruit water ratio (R)	Yeast concentration (C)					
	C_1 (0.5 %)		C_2 (0.75 %)		C_3 (1%)	
	Cl_1 (Pectinase)	Cl_2 (Settling)	Cl_1 (Pectinase)	Cl_2 (Settling)	Cl_1 (Pectinase)	Cl_2 (Settling)
R_1(1:0.75)	21.51	20.86	24.83	23.50	18.87	23.83
R_2 (1:1)	19.21	20.53	21.51	21.85	24.50	21.18
R_3 (1:2)	11.92	12.90	13.22	13.25	15.55	15.22
CD (R x C x Cl)	2.56					

69

4. 2. 4. Rose apple

4. 2. 4. 1. Chemical evaluation

The chemical quality parameters of the rose apple wines were evaluated and shown in Tables 18-22.

1. TSS (^{0} Brix)

No significant difference was observed between the TSS content of different rose apple wines (Table 18.). However highest TSS value (6.4^{0}Brix) was recorded in wines produced using 1:0.75 fruit: water ratio and 0.75% yeast irrespective of clarification methods. Least TSS (5.2^0 Brix) was recorded in wine produced using 1:2 fruit: water ratio, 1% yeast and clarified by settling.

2. Acidity (% titrable acidity as citric acid)

Wines showed significant difference in acidity content (Table 19.). The lowest acidity (0.25%) was seen in the wines prepared using1:1 fruit: water ratio and with 1% yeast irrespective of clarification methods. This wine was on par with all the wines produced using 1:0.75 fruit: water ratio. The highest acidity (0.69%) was recorded in wine prepared using fruit: water ratio1:1, with 0.75% yeast and clarified using pectinase, which in turn was, on par with the wine prepared in the same manner but clarified by settling (0.64%).

3. Alcohol content (%)

There was significant difference between the alcohol content of different rose apple wines (Table 20.). Alcohol content was highest (12.01%) when the wine was produced with 1:2 fruit: water ratio, 0.75% yeast and clarified using pectinase. The wines produced using the same fruit: water ratio, 1% yeast and clarified by pectinase (11.13%) and settling (11.42%) and the wine produced with 1:2 fruit: water ratio, 0.5 % yeast and clarified using pectinase (11.13%) had similar alcohol content. Wine which was produced using 1:1 fruit: water ratio, 1% yeast and clarified by settling had recorded least alcohol content (5.27%).

Table 18. Effect of fruit water ratio, yeast concentration and clarification on TSS of rose apple wines

TSS(^{0} Brix)						
Fruit water ratio (R)	Yeast concentration (C)					
	C_1 (0.5 %)		C_2 (0.75 %)		C_3 (1%)	
	Cl_1 (Pectinase)	Cl_2 (Settling)	Cl_1 (Pectinase)	Cl_2 (Settling)	Cl_1 (Pectinase)	Cl_2 (Settling)
R_1(1:0.75)	6.0	6.0	6.4	6.4	6.0	5.8
R_2 (1:1)	5.8	5.4	6.0	6.0	6.0	6.0
R_3 (1:2)	5.8	6	6.0	5.6	5.4	5.2
CD (R x C x Cl)	NS					

Table 19. Effect of fruit water ratio, yeast concentration and clarification on acidity of rose apple wines

Acidity (%)						
Fruit water ratio (R)	Yeast concentration (C)					
	C_1 (0.5 %)		C_2 (0.75 %)		C_3 (1%)	
	Cl_1 (Pectinase)	Cl_2 (Settling)	Cl_1 (Pectinase)	Cl_2 (Settling)	Cl_1 (Pectinase)	Cl_2 (Settling)
R_1(1:0.75)	0.30	0.28	0.38	0.41	0.49	0.51
R_2 (1:1)	0.54	0.61	0.69	0.64	0.25	0.25
R_3 (1:2)	0.38	0.56	0.54	0.44	0.51	0.41
CD (R x C x Cl)	0.05					

Table 20. Effect of fruit water ratio, yeast concentration and clarification on alcohol content of rose apple wines

Alcohol content (%)						
Fruit water ratio (R)	Yeast concentration (C)					
	C_1 (0.5 %)		C_2 (0.75 %)		C_3 (1%)	
	Cl_1 (Pectinase)	Cl_2 (Settling)	Cl_1 (Pectinase)	Cl_2 (Settling)	Cl_1 (Pectinase)	Cl_2 (Settling)
R_1(1:0.75)	9.08	10.25	9.08	7.61	11.13	8.20
R_2 (1:1)	7.90	6.73	8.20	7.02	8.20	5.27
R_3 (1:2)	11.13	10.54	12.01	9.08	11.13	11.42
CD (R x C x Cl)	1.38					

4. Polyphenol content (mgg^{-1})

Polyphenol content of different rose apple wines varied significantly (Table 21.). Polyphenol content was least (30.18 mgg^{-1}) when the wine was prepared with 1:0.75 fruit: water ratio, 0.5% yeast and clarified by settling. This wine was on par with the wine which was prepared using the same fruit: water ratio, but with 0.75% yeast and clarified using pectinase (36.47mgg^{-1}). Maximum polyphenol content (110.37 mgg^{-1}) was recorded in wine produced using 1:2 fruit: water ratio, 1% yeast and clarified using pectinase and it was on par with the wine produced in the same manner but clarified by settling (108.80 mgg^{-1}).

5. Antioxidant activity (%)

There was significant difference between the antioxidant activity of different rose apple wines (Table 22.). Antioxidant activity was highest (97.81%) when the wine was prepared using 1:2 fruit: water ratio, 1% yeast and clarified by settling. This was followed by wine which was prepared in the same manner but clarified using pectinase (92.50%) which was on par with the wine produced with the same fruit: water ratio, 0.75% yeast and clarified by settling (91.56%). The antioxidant activity was least (24.97%) when the wine was prepared using 1:0.75 fruit: water ratio, 0.5% yeast and clarified by settling which is on par with the wine produced in the same manner but clarified using pectinase (25.00%).

***4. 2. 4. 2.* Sensory evaluation**

Different papaya wines were analysed for various sensory attributes using 9point hedonic scale to assess their acceptance (Table 23).

1. Appearance

The rose apple wines prepared using 1:2 fruit: water ratio and 0.75% yeast had irrespective of clarification method the highest mean score (7.7) for appearance. The wine prepared using 1:0.75 fruit: water ratio, 0.5% yeast and clarified by pectinase had the least mean score (1.7) for appearance.

Table 21. Effect of fruit water ratio, yeast concentration and clarification on polyphenol content of rose apple wines

Polyphenol content (mgg^{-1})						
Fruit water ratio (R)	Yeast concentration (C)					
	C_1 (0.5 %)		C_2 (0.75 %)		C_3 (1%)	
	Cl_1 (Pectinase)	Cl_2 (Settling)	Cl_1 (Pectinase)	Cl_2 (Settling)	Cl_1 (Pectinase)	Cl_2 (Settling)
R_1(1:0.75)	37.26	30.18	36.47	45.90	54.55	66.34
R_2 (1:1)	71.06	60.05	63.99	65.56	48.26	50.62
R_3 (1:2)	82.07	75.78	93.07	97.79	110.37	108.80
CD (R x C x Cl)	6.67					

Table 22. Effect of fruit water ratio, yeast concentration and clarification on antioxidant activity of rose apple wines

Antioxidant activity (%)						
Fruit water ratio (R)	Yeast concentration (C)					
	C_1 (0.5 %)		C_2 (0.75 %)		C_3 (1%)	
	Cl_1 (Pectinase)	Cl_2 (Settling)	Cl_1 (Pectinase)	Cl_2 (Settling)	Cl_1 (Pectinase)	Cl_2 (Settling)
R_1(1:0.75)	25.00	24.97	35.62	33.75	50.00	51.87
R_2 (1:1)	59.37	56.87	69.68	72.50	75.62	76.87
R_3 (1:2)	83.75	84.37	88.12	91.56	92.50	97.81
CD (R x C x Cl)	2.23					

2. *Colour*

The highest mean score for colour (8.3) was recorded in wine prepared using 1:2 fruit: water ratio, 0.75% yeast and clarified by settling, followed by the wine produced in the same manner but clarified by pectinase (8.2). The lowest mean score for colour (1.5) was obtained for the wine prepared using 1:0.75 fruit: water ratio, 0.5% yeast and clarified by pectinase.

3. *Flavour*

The highest mean score for flavour (7.6) was obtained for the wine prepared using 1:2 fruit: water ratio, 0.75% yeast and clarified by pectinase. The lowest mean score (1.6) was recorded for wine prepared using 1:0.75 fruit: water ratio, 0.75% yeast and clarified by pectinase.

4. *Texture*

The highest mean score for texture (5.7) was obtained for the wine prepared using 1:2 fruit: water ratio, 0.75% yeast and clarified by pectinase followed by the wine prepared in same manner clarified by settling (4.6). The lowest mean score (1.6) for texture was obtained for the wine prepared from 1:0.75 fruit: water ratio, 0.5% yeast and clarified by pectinase.

5. *Taste*

The highest mean score for taste (6.6) was recorded for the wine prepared using 1:2 fruit: water ratio, 0.5% yeast and clarified by settling. This was followed by the wines prepared from the same fruit: water ratio, 0.75% yeast, irrespective of clarification method (5.8). The least prefered wine in terms of taste (2.0) was the one prepared from 1:0.75 fruit: water ratio, 0.75% yeast and clarified by settling.

6. *Aftertaste*

The wine prepared from 1:2 fruit: water ratio, 0.75% yeast and clarified by settling had highest score for aftertaste (5.8) which was closely followed by the wine prepared in the same manner but clarified by pectinase (5.7). The wines with least score for aftertaste were the one prepared using 1:1 fruit: water ratio, 0.5%

Table 23. Effect of fruit water ratio, yeast concentration and clarification on sensory quality of rose apple wines

Treatments	Appearance		Colour		Flavour		Texture		Taste		After taste	
	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank
T_1 -1:0.75 F-W + 0.5% Yeast + Pectinase	1.7	16.00	1.5	9.75	2.1	36.70	1.6	20.50	2.2	38.60	2.4	42.50
T_2 -1:0.75 F-W + 0.5% Yeast + Settling	2.4	29.20	2.5	29.75	3.0	68.20	1.7	25.80	2.5	48.70	2.7	53.75
T_3 -1:0.75 F-W + 0.75% Yeast + Pectinase	4.4	77.30	3.6	58.15	1.6	24.20	3.9	97.30	2.7	53.90	3.0	65.00
T_4 -1:0.75 F-W + 0.75% Yeast + Settling	4.5	81.10	4.5	84.50	2.7	57.40	4.2	103.45	2.0	32.00	3.6	86.30
T_5 -1:0.75 F-W + 1% Yeast + Pectinase	4.0	68.15	4.8	92.45	2.6	54.90	3.7	88.45	2.7	50.70	2.5	46.25
T_6 -1:0.75 F-W + 1% Yeast + Settling	7.4	145.40	7.3	142.95	3.1	72.00	3.6	85.30	2.3	38.30	4.0	98.80
T_7 -1:1 F-W + 0.5% Yeast + Pectinase	7.6	152.65	7.1	139.15	7.4	163.05	2.9	63.5	5.3	132.50	2.3	42.95
T_8 -1:1 F-W + 0.5% Yeast + Settling	5.4	100.70	7.4	145.10	3.0	68.30	4.3	111.05	4.1	96.10	2.5	47.65
T_9 -1:1 F-W + 0.75% Yeast + Pectinase	6.6	127.00	5.4	106.50	3.2	75.60	3.0	61.70	3.5	77.50	2.3	41.55
T_{10} -1:1 F-W + 0.75% Yeast + Settling	3.7	61.10	3.6	60.15	3.8	94.40	4.2	108.75	4.0	93.80	4.7	124.65
T_{11} -1:1 F-W + 1% Yeast + Pectinase	6.4	106.90	4.8	90.95	1.9	34.00	2.5	47.85	2.2	40.00	3.6	87.10
T_{12} -1:1 F-W + 1% Yeast + Settling	7.3	140.45	7.1	137.25	4.1	105.40	4.2	103.60	4.3	103.90	3.4	81.00
T_{13} -1:2 F-W + 0.5% Yeast + Pectinase	3.5	54.50	3.3	51.95	3.7	87.65	3.8	92.55	5.1	122.70	4.3	110.70
T_{14} -1:2 F-W + 0.5% Yeast + Settling	3.4	54.20	4.4	82.10	5.1	127.70	3.7	89.95	6.6	160.00	4.9	129.25
T_{15} -1:2 F-W + 0.75% Yeast + Pectinase	7.7	153.95	8.2	162.05	7.6	165.45	5.7	153.50	5.8	144.80	5.7	153.75
T_{16} -1:2 F-W + 0.75% Yeast + Settling	7.7	152.65	8.3	163.00	6.1	141.05	4.6	121.85	5.8	146.00	5.8	155.30
T_{17} -1:2 F-W + 1% Yeast + Pectinase	2.6	34.00	2.4	27.10	5.7	139.50	3.8	92.55	4.7	114.70	5.0	130.15
T_{18} -1:2 F-W + 1% Yeast + Settling	4.3	73.75	3.1	46.15	4.6	113.50	4.2	103.45	5.4	134.80	5.0	132.35
K value	135.29		152.56		122.80		89.91		123.45		105.24	
χ^2	27.587		27.587		27.587		27.587		27.587		27.587	

yeast and clarified by pectinase (2.3) and the wine prepared in the same manner but with 0.75% yeast.

4.3. SELECTION OF BEST FRUIT WINE

Based on chemical and sensory quality parameters, wines having superior quality parameters were identified from each fruit for selecting the best one.

4.3.1. Carambola

Wines having superior quality parameters	Characteristics
T_3 (1:0.75 Fruit: water ratio + 0.75% Yeast + Pectinase)	Highest antioxidant activity (82.4%) Least score for flavour (2.2) Low scores for other sensory parameters
T_{15} (1:2 Fruit: water ratio + 0.75% Yeast + Pectinase)	Highest antioxidant activity (64.9%), Low polyphenol content (183.63 mgg^{-1}) Highest score for texture (5.2) and comparatively high scores for other sensory attributes
T_{17} -1:2 Fruit: water ratio + 1% Yeast + Pectinase	Highest score (6.0) for taste Low antioxidant activity (32.4 %)
T_{18}-1:2 Fruit: water ratio +1% Yeast + Settling	Good score for after taste (5.8) Low antioxidant activity (43.4%)
T_6 -1:0.75 Fruit: water ratio + 1% Yeast + Settling	Highest score for appearance (8.5) and colour (8.4) Low antioxidant activity (21.5%).

4.3.2. Jamun

The beverage prepared from jamun had high acidity content (0.69-5.42%), a pungent smell, vinegary flavour and an unpleasant taste. Hence they could not be subjected to sensory evaluation.

4.3.3. Papaya

Wines having superior quality parameters	Characteristics
T_{15} -1:2 Fruit: water ratio + 0.75% Yeast + Pectinase	High antioxidant activity (66.88%) Lower polyphenol content (181.91mgg^{-1}) Highest score for appearance (7.1), colour (7.9) and flavour (8.2).
T_{16} -1:2 Fruit: water ratio + 0.75% Yeast + Settling	Highest rank for texture (8.2), Lower antioxidant activity (64.89%).
T_{17} -1:2 Fruit: water ratio + 1% Yeast + Pectinase	Highest antioxidant activity (79.46%) High polyphenol content (181.91mgg^{-1}), highest mean score for after taste (6.0) and a higher score for taste (5.7).

4.3.4. Rose apple

Wines having superior quality parameters	Characteristics
T_{18} (1:2 Fruit: water ratio + 1% Yeast + Settling)	Highest antioxidant activity (97.81%) High polyphenol content (108.80 mgg^{-1}) Low sensory score for flavour (4.6), after taste (5.0), appearance (4.3), and colour (3.1).
T_{17} -1:2 Fruit: water ratio + 1% Yeast + Pectinase	High antioxidant activity (92.50%) High polyphenol content (110.37 mgg^{-1}) Very low score for sensory quality parameters like taste (4.7) and after taste (5).
T_{16} -1:2 Fruit: water ratio + 0.75% Yeast + Settling	Higher antioxidant activity (91.56%) Lower polyphenol content (97.79 mgg^{-1}) Highest sensory score for appearance (7.7), colour (8.3) and after taste (5.8).

As all the chemical and sensory parameters were not recorded in a single wine, overall acceptability of the wines were calculated for selection of best wine (Table 24).

When overall acceptability was calculated, the highest mean score (6.1) was obtained for the carambola wine prepared using 1:2 fruit: water ratio, 0.75% yeast and clarified by pectinase.

The highest mean score for overall acceptability (4.7) was obtained for the papaya wine prepared using 1:2 fruit: water ratio, 0.75% yeast and clarified by pectinase. This was closely followed by the wine (4.6) prepared using the same method but with 1% yeast.

Due to high acidity content and the pungent vinegary taste, the beverage prepared from jamun could not be subjected to sensory analysis.

The highest mean score overall acceptability (5.4) was obtained for the Rose apple wine prepared using 1:2 fruit: water ratio, 0.75% yeast and clarified by settling.

Based on the antioxidant activity and overall acceptability, the following best wines were selected from each fruit individually as shown below.

Carambola	T_{15} (1:2 fruit: water ratio+ 0.75% yeast and clarified by pectinase)
Papaya	T_{17} (1:2 fruit: water ratio+ 1% yeast and clarified by pectinase)
Jamun	Not Selected
Rose apple	T_{16} (1:2 fruit: water ratio+ 0.75% yeast and clarified by settling)

4.4. STORAGE POTENTIAL OF FRUIT WINE

The best wine selected from each fruit based on overall acceptability and antioxidant activity was stored under ambient condition for a period of three months in two different packaging materials for analysing the storage stability.

78

Table 24. Overall acceptability of fruit wines

Overall acceptability score						
	Carambola		Papaya		Rose apple	
Treatments	MS	Rank	MS	Rank	MS	Rank
T_1 -1:0.75 F-W + 0.5% Yeast + Pectinase	2.1	44.59	2.2	53.50	2.2	35.10
T_2 -1:0.75 F-W + 0.5% Yeast + Settling	2.8	50.63	2.7	43.05	2.4	29.95
T_3 -1:0.75 F-W + 0.75% Yeast + Pectinase	4.3	94.36	3.9	90.75	3.8	81.05
T_4 -1:0.75 F-W + 0.75% Yeast + Settling	3.8	76.09	4.6	115.60	3.9	80.10
T_5 -1:0.75 F-W + 1% Yeast + Pectinase	4.3	93.90	4.2	106.55	4.2	95.45
T_6 -1:0.75 F-W + 1% Yeast + Settling	4.8	104.18	3.3	67.55	3.8	84.10
T_7 -1:1 F-W + 0.5% Yeast + Pectinase	4.8	107.63	4.6	108.20	4.4	99.90
T_8 -1:1 F-W + 0.5% Yeast + Settling	5.6	115.22	4.4	104.95	4.6	112.15
T_9 -1:1 F-W + 0.75% Yeast + Pectinase	4.8	106.27	3.9	94.30	4.4	102.60
T_{10} -1:1 F-W + 0.75% Yeast + Settling	4.1	78.22	3.2	64.00	4.0	88.30
T_{11} -1:1 F-W + 1% Yeast + Pectinase	3.5	68.36	2.9	50.15	3.6	71.50
T_{12} -1:1 F-W + 1% Yeast + Settling	4.2	92.59	3.6	80.45	3.9	85.30
T_{13} -1:2 F-W + 0.5% Yeast + Pectinase	4.1	87.27	3.5	77.00	4.2	95.35
T_{14} -1:2 F-W + 0.5% Yeast + Settling	4.7	106.36	4.1	104.60	4.7	115.15
T_{15} -1:2 F-W + 0.75% Yeast + Pectinase	6.1	137.90	4.7	118.35	5.2	124.70
T_{16} -1:2 F-W + 0.75% Yeast + Settling	5.8	126.90	4.6	115.65	5.4	133.05
T_{17} -1:2 F-W + 1% Yeast + Pectinase	5.1	116.31	4.6	109.00	4.5	102.90
T_{18} -1:2 F-W + 1% Yeast + Settling	4.8	103.63	3.9	92.70	4.1	92.35
K value	50.72		44.20		45.46	
χ^2	27.587		27.587		27.587	

4. 4. 1. Carambola

4. 4. 1. 1. Chemical evaluation

Polyphenol and alcohol content of the best wine were analysed initially and during the first and third month of storage (Table 25.)

1. Polyphenol content (mgg^{-1})

The polyphenol content of wine was 183.63 mgg^{-1} at the time of storage. There was significant difference between the polyphenol content of wines stored in different bottles. Polyphenol content of the wine stored in amber coloured bottle was higher compared to those stored in plain bottle and it was 172.71 mgg^{-1} and 156.09 mgg^{-1} during first and third month of storage respectively. Polyphenol content decreased during storage period irrespective of packaging materials.

2. Alcohol content (%)

The alcohol content of wine was 8.9% at the time of storage and the content increased during storage period in both the containers. There was significant difference in the alcohol content of wines stored in different bottles. Alcohol content of wine stored in amber coloured bottle was higher compared to the wine stored in plain glass bottles. The alcohol contents in amber coloured bottles were 9.40 % and 10.37 % during first and third month respectively whereas; it was 9.25 % and 9.73 % in plain glass bottle.

4. 4. 1. 2. Microbial evaluation

The microbial (bacterial) load (Table.26) in carambola wine was too low to count (TLTC) at the time of storage. There was no significant difference between the microbial load of carambola wines stored in different bottles or recorded during different storage periods.

Table 25. Effect of storage on polyphenol and alcohol content of carambola wine

Packaging materials	Polyphenol Content (mgg^{-1})				Alcohol Content (%)			
	Months after storage				Months after storage			
	0	1	3	CD	0	1	3	CD
Glass	183.63	169.12	151.37	1.87	8.90	9.25	9.73	0.10
Amber		172.71	156.09	2.13		9.40	10.37	0.07
CD		2.00	2.35			0.10	0.07	

Table 26. Effect of storage on microbial load in carambola wine

Treatments	Microbial load (cfu)			
	Months after storage			
	0	1	3	CD
Glass	TLTC	28.83	33.66	NS
Amber		45.00	51	NS
CD		NS	NS	

(TLTC- Too low to count) (cfu-colony forming units)

4. 4. 2. Papaya

4. 4. 2. 1. Chemical evaluation

Polyphenol and alcohol content of the best papaya wine were analysed initially and during the first and third month of storage (Table 27).

1. ***Polyphenol content (mgg^{-1})***

The polyphenol content of wine was 201.57 mgg^{-1} at the time of storage. There was significant difference between the polyphenol content of wines stored in different bottles. Polyphenol content of the wine stored in amber coloured bottle was higher compared to those stored in plain bottle and it was 193.48 mgg^{-1} and 182.82 mgg^{-1} during first and third month of storage respectively whereas, in glass bottles the content was 188.09 mgg^{-1} and 181.80 mgg^{-1} during first and third month of storage respectively. Polyphenol content decreased during storage period irrespective of packaging materials.

2. ***Alcohol content (%)***

The alcohol content of wine was 6.15% at the time of storage and the content increased during storage period irrespective of the containers. There was significant difference in the alcohol content of wines stored in different bottles. Alcohol content of wine stored in amber coloured bottle was higher compared to the wine stored in plain glass bottles. The alcohol contents in amber coloured bottles were 7.53 % and 8.79 % during first and third month respectively whereas; it was 7.11 % and 8.20 % in plain glass bottle.

4.4. 2. 2. Microbial evaluation

The microbial (bacterial) load (Table.28) in papaya wine was too low to count (TLTC) at the time of storage. There was no significant difference between the microbial load of papaya wines stored in different bottles or recorded during different storage periods.

Table 27. Effect of storage on polyphenol and alcohol content of papaya wine

Packaging materials	Polyphenol Content (mgg^{-1})				Alcohol Content (%)			
	Months after storage				Months after storage			
	0	1	3	CD	0	1	3	CD
Glass	201.57	188.09	181.80	1.79	6.15	7.11	8.20	0.18
Amber		193.48	183.82	2.60		7.53	8.79	0.18
CD		2.83	1.41			0.25	NS	

Table 28. Effect of storage on microbial load in papaya wine

Treatments	Microbial load (cfu)			
	Months after storage			
	0	1	3	CD
Glass	TLTC	16.16	30.83	NS
Amber		12.00	18.16	NS
CD		NS	NS	

(TLTC- Too low to count) (cfu-colony forming units)

4. 4. 4. Rose apple

4. 4. 4. 1. Chemical evaluation

Polyphenol and alcohol content of the best wine were analysed initially and during the first and third month of storage (Table 29.)

*1. **Polyphenol content (mgg^{-1})***

The polyphenol content of wine was 97.79 mgg^{-1} at the time of storage. Wines stored in different bottles showed significant difference in the polyphenol content during storage. The content was higher in wine stored in amber coloured bottle compared to those stored in plain bottle and it was 94.20 mgg^{-1} and 84.32 mgg^{-1} during first and third month of storage respectively. Irrespective of packaging materials used polyphenol content decreased during storage period.

*2. **Alcohol content (%)***

The alcohol content of wine was 9.08% at the time of storage and the content increased during storage period in both the containers. There was significant difference in the alcohol content of wines stored in different bottles. Compared to the wine stored in plain glass bottles, alcohol content of wine stored in amber coloured bottles was higher. The alcohol contents in amber coloured bottles were 11.05 % and 12.22 % during first and third month respectively whereas; it was 10.21 % and 11.55 % in plain glass bottle.

4.4. 4. 2. Microbial evaluation

The microbial (bacterial) load (Table 30) in rose apple wine was too low to count (TLTC) at the time of storage. Microbial load of rose apple wines stored in different bottles or recorded during different storage periods did not show any significant difference.

Table 29. Effect of storage on polyphenol and alcohol content of rose apple wine

Packaging materials	Polyphenol Content (mgg^{-1})				Alcohol Content (%)			
	Months after storage				Months after storage			
	0	1	3	CD	0	1	3	CD
Glass	97.79	89.71	78.03	2.82	9.08	10.21	11.55	0.60
Amber		94.20	84.32	2.19		11.05	12.22	0.26
CD		2.71	2.33			0.50	0.37	

Table 30. Effect of storage on microbial load in rose apple wine

Treatments	Microbial load (cfu)			
	Months after storage			
	0	1	3	CD
Glass	TLTC	15.00	23.16	NS
Amber		12.83	13.33	NS
CD		NS	NS	

(TLTC- Too low to count) (cfu-colony forming units)

Discussion

5. DISCUSSION

Underexploited fruits are known for their therapeutic and nutritive values and hence classified under the category of neutraceuticals. Because of their inherent medicinal properties, they have been used in traditional Indian systems of medicine since time immemorial. Many have excellent flavour and very attractive colour. Colour in these fruits because of the presence of specific pigments is gaining importance nowadays as they play a vital role in human health and nutrition because of their antioxidant properties. Value addition to such fruits would not only promote economic status of people but promote health and nutrition status of people consuming such fruits.

The term "fruit wine" is applied to alcoholic fermented drinks produced from fruits other than grapes. Fruit wine is defined as a wine produced from fruit other than grapes. It is produced by the normal alcoholic fermentation of the juice of sound, ripe fruit including restored or unrestored pure condensed fruit must. Any fruit with reasonable amounts of fermentable sugars can be utilized for the production of wine.

Fruit wines were prepared from four different underexploited fruits viz., carambola, papaya, jamun and rose apple independently by varying three process parameters viz., fruit: water ratio, yeast concentration and clarification methods. Fruit: water ratio was tried at 1:0.75, 1:1 and 1:2; yeast concentration at 0.5, 0.75 and 1% and clarification by pectinase enzyme and by settling, thus forming 18 different fruit wines in each fruit.

The results obtained from the investigation on "Standardization of quality wine production from selected underexploited fruits" are discussed in this chapter under the following headings.

1. Quality analysis of fruit wines
2. Selection of the best fruit wine
3. Storage potential of fruit wines

5.1. QUALITY ANALYSIS OF FRUIT WINES

The wines prepared by varying process parameters were analysed for different quality parameters.

1. Carambola

Star fruit (*Averrhoa carambola*) is a nutritious tropical fruit, rich in vitamins (vitamin B, C), oxalic acid, polyphenols, dietary fiber, volatile compounds, etc which could be converted to wines (Plate 3.) with a fermented yield of 63.8 to 138.8% in the present experiment. Color of the prepared carambola wine was observed to be golden yellow; they were brilliant (sparkling clear) to cloudy and had a predominant astringent taste compared to fruity taste.

When the chemical quality parameters of the carambola wines were analysed, the TSS content varied from 2.8 to 4.6 ^{0} brix and the acidity content ranged from 0.3 to 0.6%, but there was no significant difference between the TSS and acidity content of different wines. The TSS content varied from 2.8 to 4.6 ^{0} brix and the acidity content ranged from 0.3 to 0.6%.

Sugars (Total sugars and reducing sugars) were absent or not detectable in all the prepared carambola wines. During alcoholic fermentation, biochemical activity of yeast changes the physical and chemical composition of the fruit used; the simple sugars, nitrogen compounds and other molecules present in the substrate will be transformed and the increase in alcohol production occurs. The decrease in total sugar and increase in ethanol content are in conformity to the results of Chikkasubbanna et al. (1990). Here all the fermentable sugars present in the substrate might have been fully converted into ethyl alcohol during wine production. Hence all the prepared

Plate.3. Carambola Wines

carambola wines belonged to "Dry wines". Dry wine is a type of wine with no residual sugar. Dry, semidry, or sweet wines of acceptable quality were produced from carambola (Anon, 1992). The TSS recorded in the resultant wines of the present study may be due to the presence of soluble solids other than sugars present in the substrate.

Thin Layer Chromatography (TLC) carried out by Napahde *et al.* (2010) revealed that the predominant sugar in the carambola juice is the fermentable sugar (sucrose), which could support the growth of ethanol fermenting microorganisms; but the amounts of these sugars present were reported to be, too low for adequate alcohol production, to call the product a wine. When dealing with fruits other than grapes, sugar may need to be added to spur the fermentation process in the event that the fruit does not contain enough natural sugar to ferment on its own in the presence of yeast (Pande and Akoh., 2010). The raw material selected for the present experiment had a TSS content of 7^0 brix only, but additional refined sugar was added based on the initial TSS content to maintain the brix of substrate as 20^0. Even then the alcohol content of the carambola wines ranged from 7.2 to 12.3% only, indicating that they belonged to light or medium wines. The results indicated that added sugar and yeast starter culture helped in increasing the alcohol content. Lewis and Grocizam (1989) reported that some sweet cultivars of carambola are said to have high carbohydrates (specifically glucose) content and pH around 4, which make their processing into wine more feasible. The highest alcohol content was observed when the wine was prepared using 1:2 fruit: water ratio, 1% yeast and clarified using pectinase (12.3%) and by settling (11.6%). This wine was on par with the wine which was produced in the same manner, but with 0.5 % yeast (12.0 %). The sensory panel selected for the present experiment had rated these medium wines as the one with high taste and after taste scores. All the wines prepared using 1:1 fruit: water ratio had with least alcohol content (7.2- 7.9%) except the one, to which 0.5% yeast was added and clarified by pectinase (8.2). The wines prepared using 1:1 fruit: water ratio had an acceptability score ranging from 2.1 to 6.1.

When the quality parameters viz., polyphenol content and antioxidant activity were assessed to select the best quality wine, significant difference was noticed between different fruit wines. A quality wine should have low polyphenol content to get a high sensory acceptance. Wines recorded the least polyphenol (169.40 mgg^{-1}) content when fruit: water ratio was maintained at 1:2 ratio, yeast concentration of 0.5% and clarification done by pectinase. This wine was on par with the wine which was prepared in the same manner, but with 0.75% yeast (183.63 mgg^{-1}). Polyphenol content was maximum (508.58 mgg^{-1}) when wine was produced with 1:0.75 fruit: water ratio, 0.75% yeast and clarified by settling.

Antioxidant activity was highest (82.4%) when the wine was prepared with 1: 0.75 fruit: water ratio, 0.75% yeast and clarified using pectinase, but it had least sensory score for flavour (2.2) and very low scores for other sensory quality parameters. The wines produced using 1:2 fruit: water ratio and 1% yeast and clarified using pectinase had highest score (6.0) for taste and the one clarified by settling had highest score for after taste (5.8). But these wines had low antioxidant activity. The wine prepared using 1:0.75 fruit: water ratio, 1% yeast and clarified by settling had the highest mean score for appearance (8.5) and colour (8.4), but they had low antioxidant activity (21.5%) only. Sensory evaluation by Paul and Sahu (2014) has showed that the carambola wine possessed very good taste, aroma, and clarity with moderately good body and aftertaste.

The antioxidant activity was high (64.9%) and polyphenol content was low (183.63 mgg^{-1}) when the wine was prepared using 1:2 fruit: water ratio, 0.75% yeast and pectinase as clarifying agent and it had highest score for texture (5.2) and comparatively high scores for all other sensory attributes. The results clearly showed that a single wine had no superior scores for all the sensory quality parameters tested.

Valim et al. (2016) standardised the best conditions for the production of carambola wines as initial soluble solids between 23.8 and 25 °Brix and initial concentration of yeast between 1.6 and 2.5 g $L^{-1}$to yield a fermented drink with an alcohol content of 11.15 %, low levels of total acidities and fermented yield from 82 to 94 %. The difference in wine quality obtained in the present experiment might be due to the difference in quality of raw material used and the conditions maintained during the experiment. Lakshmana et al. (2006) had also reported that the wine prepared from the 24^0 brix must of carambola fruit has acceptable sensory qualities supported by different physical and chemical characters. The maintenance of initial TSS level to 24-25^0 brix instead of 20^0 brix would have produced carambola wine of higher quality in the present experiment.

2. Papaya

The tropical fruit Papaya (*Carica papaya)* is a good source of carbohydrate, vitamins and minerals especially copper and magnesium (Wall, 2006). This fruit is well known for its medicinal properties mainly owing to the presence of the proteolytic enzyme papain which aids in digestion. Its sweet taste, vibrant colour and the wide health benefits make it a popular fruit and could be processed into wines (Plate 4.) with a fermented yield of 20.6 to 86% in the present study.

The wines prepared from papaya had a light yellowish colour with the characteristic odour of papaya. Umeh et al. (2015) prepared papaya wine with a brilliant yellow color and a slight sweet flavor.

Analysis of the chemical quality parameters of the papaya wines showed no significant difference between the TSS and acidity content of different wines. However, the TSS content ranged between 3.0 to 4.4 ^{0} Brix and the acidity ranged from 0.25 to 0.65 %. According to Awe (2011), aerobic fermentation, caused the pH drop from 4.4 to 3.1, titratable acidity increased from 0.2 to 0.4 % in papaya wines.

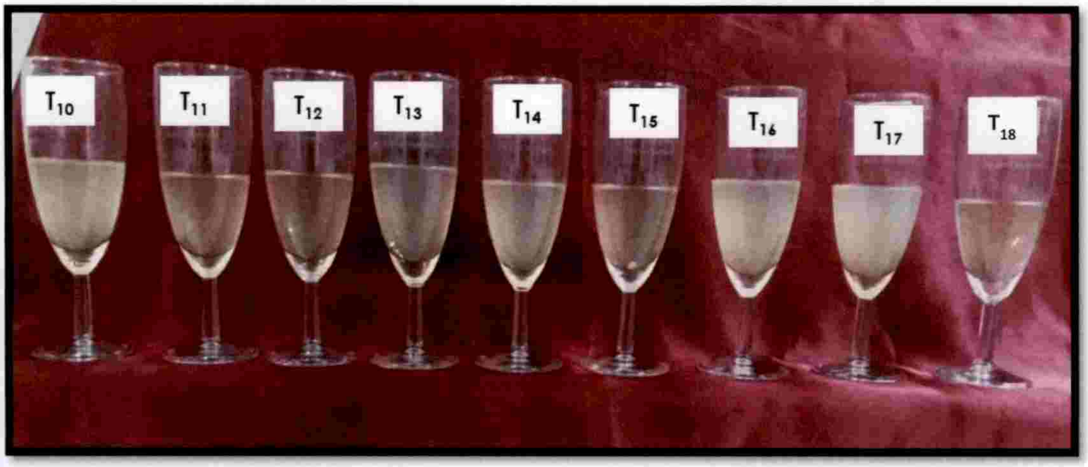


Plate.4. Papaya Wines

During the fermentation process, acidification of the medium occurs which is crucial for wine production. Acidity plays an important role in the wine quality by helping in fermentation process and improving the overall characteristics and balance of the wine. Lack of acidity will cause poor fermentation (Berry, 2000).

Both total and reducing sugars were absent in all the papaya wines produced, indicating that they are "Dry" in nature. The sugar content in the must decreases gradually during fermentation. According to Joshi *et al.*, 2013, the process of fermenting is basically feeding sugars and nutrients in solution to yeast, which in return produces carbon dioxide gas and alcohol. This process goes on until either all the sugar is gone or the yeast can no longer tolerate the alcoholic percentage of the beverage dry wine. Awe (2011) reported a drop in sugar from 15 to 1% during the aerobic fermentation of papaya. Acidity of wines lies between pH 3 and 7 for dry wine and 3.5 to 4.5 for a sweet wine. The composition of organic acids is a crucial trait that determines the acidity of the wine (Das *et al.*, 2012)

The alcohol content of the papaya wine ranged from 6.15 to 17.28%. Alcohol content was highest when the papaya wine was prepared using 1:1 fruit: water ratio, 0.75% yeast and clarified by settling which was on par with wine produced in the same manner but clarified using pectinase (16.36%). Fruit wines usually have an alcohol content ranging between 5 and 13% (Joshi et al., 2012). Papaya is a sugar crop with soluble saccharides in the form of glucose, fructose and sucrose. Sugars represent that part of the fruits which is used by microorganisms for wine production and Ayanru et al. (1985) showed that yeast has a capacity of generation of ethanol by microbial conversion of sugar in papaya fruit. In a study by Maragatham and Panneerselvam (2011), the alcohol content in papaya wine showed an increasing trend during fermentation. The wines produced using 1:2 fruit: water ratio with 1% yeast and 1:0.75 fruit: water ratio with 0.5% yeast both clarified using pectinase had the least alcohol content of 6.15%. Umeh et al. (2015) reported that papaya can be successfully used in the production of low sugar table wine and they had produced papaya wine with an alcoholic content of 10.14%. The high alcohol content in the present experiment is due to the difference in sugar content of the selected raw material.

The wine prepared using 1:2 fruit: water ratio, 0.75% yeast and clarified using pectinase had high antioxidant activity (66.88%), lower polyphenol content (181.91mgg^{-1}) and highest ranks for appearance (7.1), colour (7.9) and flavour (8.2). The wine prepared using the same procedure, but clarified by settling had highest rank for texture (8.2) and lower antioxidant activity (64.89%). When yeast concentration was increased to 1% , must was prepared in 1:2 ratio and clarification was done using pectinase, the resultant wine had highest antioxidant activity (79.46%), high polyphenol content (181.91mgg^{-1}), highest mean score for after taste (6.0) and a higher score for taste (5.7).

Though the polyphenol content contributes an acrid taste to wine and not an acceptable character when considering the sensory attributes, it is also the factor responsible for the antioxidant activity of the wine. Polyphenolic compounds are a large and complex group responsible for the characteristics, colour and quality of wines (Mudnic *et al*., 2012). The assessment of antioxidant activity of papaya wines showed that it ranged from 14.20 to 79.46 % and the highest being recorded by the wine prepared using 1:2 fruit: water ratio, 1% yeast and clarified by settling, which makes it the most healthier wine compared to other papaya wines. Papaya fruits contain components that can increase the total antioxidant power in blood and reduce the lipid peroxidation level. These components include α-tocopherol, ascorbic acid, beta carotene, flavonoids, vitamin B1, and niacin (Ross, 1999). Ozkan et al. (2011) reported that multiple mechanisms are responsible for the antioxidant activity including phenolics.

3. Jamun

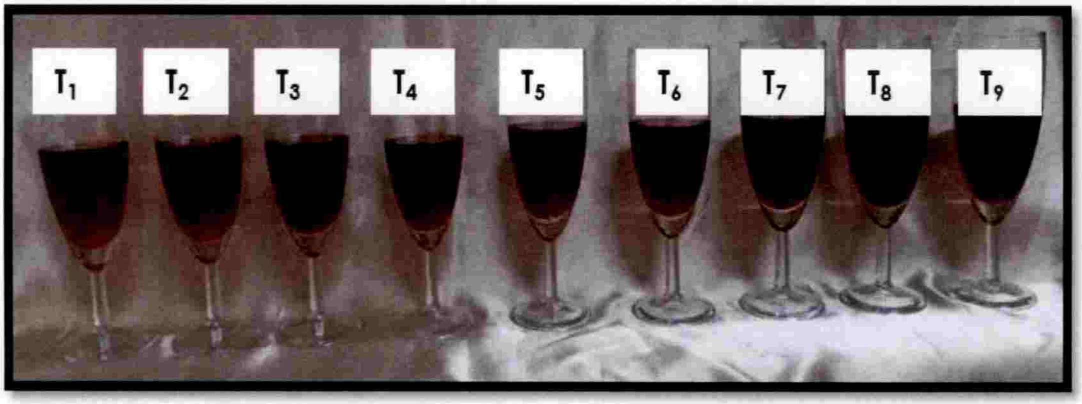
Jamun *(Syzygium cumini)* commonly known as malabar plum, an evergreen indigenous fruit of the tropics, is gaining popularity among consumers due to its balanced sugar, acid and tannin content. It is generally consumed fresh and is known to have neutraceutical and therapeutic values (Jackson and Lombard, 1993)

The drinks that were prepared from jamun had a dark purple attractive colour (Plate 5.) and there was difference in quality parameters in terms of the fruit: water ratios, yeast concentrations used and the method of clarification employed.

There was no significant difference between the TSS content of the drink. The TSS values ranged from 2.8 to 5.0^0 Brix and the alcohol content of the product ranged from 6.44 to 24%. The resultant product recorded a very high acidity range from 0.69 to 5.42% resulting in a pungent smell and vinegary taste. During primary fermentation, the fermentable sugar gets converted to alcoholic ferment which is later aged to quality wine during the secondary fermentation. These procedures are usually completed in a total period of 42 days; hence adopted in this experiment. But in the case of jamun, the ethyl alcohol might have undergone acetic fermentation within this period resulting in production of acetic acid. The physico-chemical and sensory qualities of jamun wine have been reported to be affected by the level of yeast and duration of fermentation. The polyphenol content ranged from 5.81 to 37.26 mgg^{-1} and the antioxidant activity ranged from 11.92 % to 24.83%. Shukla et al. (1991) had reported high acidity and tannin content in jamun affect the rate of fermentation and finally the quality of jamun wine. Since the product prepared from jamun had a very high acidity and pungent taste, it could not be subjected to sensory analysis and further storage studies.

4. Rose Apple

Rose apple (*Syzygium aqueum*) commonly called as water apple is the fruit of a tropical, evergreen and low growing small tree belonging to the family myrtaceae.



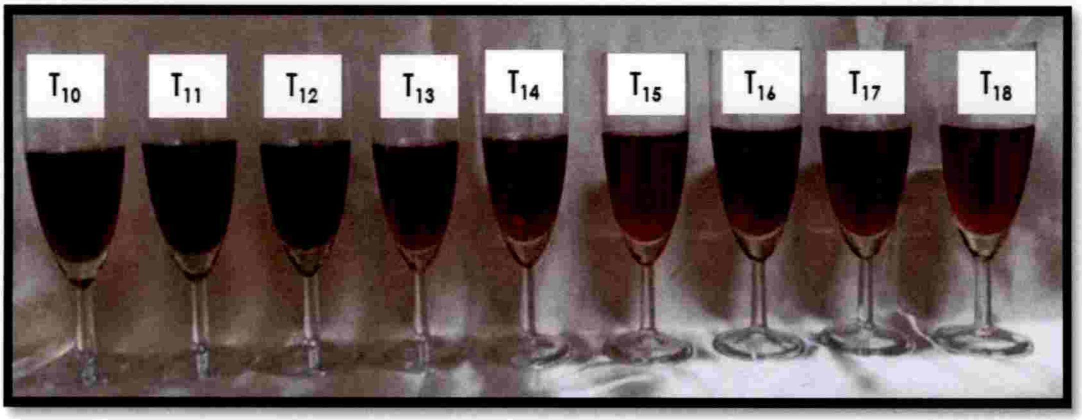


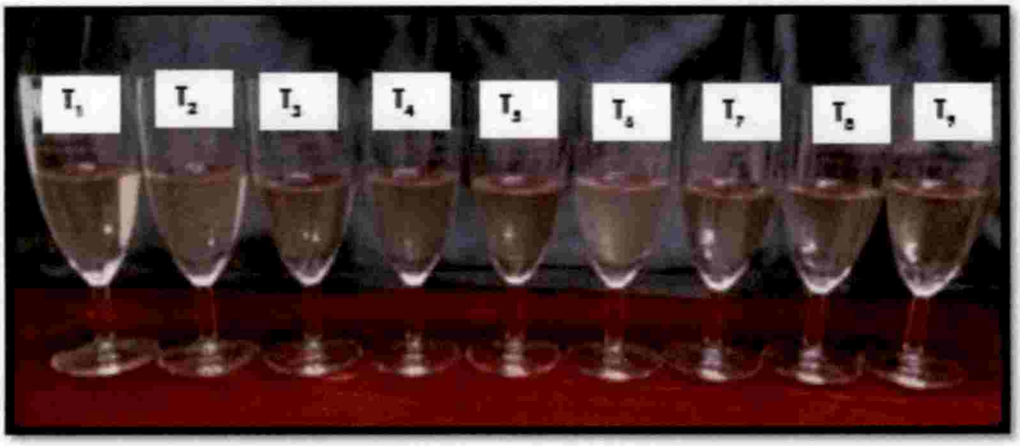
Plate.5.Jamun Wines

The fruit has a very mild and slightly sweet taste similar to apples, crisp watery texture with > 93% moisture content and could be processed into wines with a fermented yield of 52.8 to 134 % in the present study.

The wines prepared from rose apple had a light pinkish color and they were brilliant (Plate 6.) . Assessment of the chemical quality parameters of the rose apple wines showed no significant difference between the TSS content of different wines. However, the wines prepared had TSS values ranging from 5.2 to 6.4^0 Brix.

Acidity content of the rose apple wines ranged from 0.28 to 0.69%. Malic acid, one of the biologically fragile wine acids is high in rose apple juice and it is easily metabolized by several different types of wine bacteria (Lum, 1998). Malic acid is weaker than tartaric acid, so wines unusually high in malic acid can have a high titratable acidity and a high pH value. This was in line with the findings of Vazhacharikal *et al.* (2016) who reported that the acidity of rose apple wine was 5.69 ± 0.026 % after 20 days of ageing. During fermentation a reduction in the sugar content and a rise in the titratable acidity of the wine, occurs due to the action of yeast on sugars present in the fruit must. It was observed that the wine prepared using 1:1 fruit: water ratio, 0.75% yeast irrespective of clarification had the highest acidity content. The wine prepared using 1:2 fruit: water ratio, 0.75% yeast and clarified by settling had the highest mean score for color (8.3), after taste (5.8), second highest mean score for taste (5.8) and the acidity content was also lower compared to other wines (0.44%).

All the rose apple wines lacked sugar content which is due to the complete conversion of sugars to ethyl alcohol by the biochemical activity of wine yeast *Saccharomyces cerevisiae*. In a study by Swami *et al.* (2014) sugar conversion was incomplete at yeast concentration of 0.1%. At yeast concentrations (0.5%, 0.75% and 1%), the sugars might have completely been turned into alcohol. The TSS recorded in



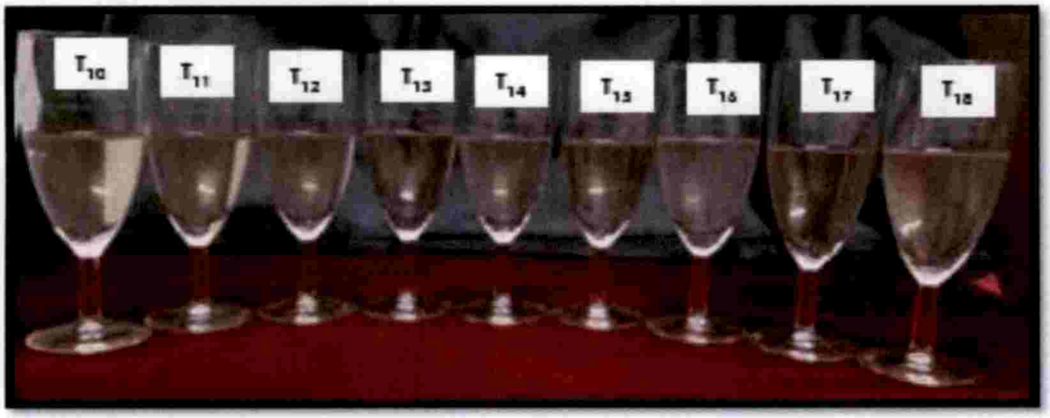


Plate.6. Rose Apple Wines

these wines may be attributed to presence of soluble solids present in the wine other than sugars.

The alcohol content of different rose apple wines varied from 5.27% to 12.01%. This was in line with the findings of Swami *et al* (2014) who had reported that fruit wines contain an alcohol per cent of 8 to 11%. The lowest alcohol content was recorded in wines prepared using 1:1 fruit: water ratio, 1% yeast and clarified by settling. The highest alcohol content was observed in wines prepared from 1:2 fruit: water ratio, 0.75% yeast and clarified using pectinase. The average sugar content of rose apple fruits varied between 2.07 and 2.53% (Bolarin *et al.*, 2016) which is very low for conversion to alcohol content.

Polyphenol content of rose apple wines was highest in the wines prepared using 1:2 fruit: water ratio and 1% yeast irrespective of clarification methods, followed by the wine prepared in the same manner but with 0.75% yeast. The lowest polyphenol content was recorded in the wine prepared using 1:0.75 fruit: water ratio, 0.5% yeast and clarified by settling.

The wine prepared using 1:2 fruit: water ratio, 1% yeast and clarified by settling had highest antioxidant activity (97.81%), high polyphenol content (108.80 mgg^{-1}) and low sensory scores for flavour (4.6), after taste (5.0), appearance (4.3), and colour (3.1). The antioxidant activity of wines is attributed by bioactive compounds especially polyphenols (Rivero Pérez et al., 2008).

Preparation of wine with 1:2 fruit: water ratio, 1% yeast and pectinase as a clarifying agent, resulted in wine with high antioxidant activity (92.50%), high polyphenol content (110.37 mgg^{-1}) and very low score for sensory quality parameters like taste (4.7) and after taste (5). Wines prepared using 1:2 fruit: water ratio, 0.75% yeast and clarified by settling had higher antioxidant activity (91.56%), lower polyphenol content (97.79 mgg^{-1}) and highest sensory score for appearance (7.7), colour (8.3) and after taste (5.8). Pink rose apple wine prepared from sliced fruit: sugar: water in 1:1: 1 scored highest score for taste in sensory evaluation (Bolarin *et al.*, 2016). According to the study conducted by Chinjirakul *et al.* (2007) fermented alcoholic beverages had a higher antioxidant activity than the original fruit. The lowest antioxidant activity was observed in the wines prepared using 1:0.75 fruit: water ratio, 0.5% yeast, irrespective of clarification methods. The choice of the substrate, climate, soil type, sugar content, strain of yeast etc. influenced the quality of the wine (Jones and Davis, 2000).

5.2. SELECTION OF THE BEST FRUIT WINE

Among the four underexploited fruits selected, all, except Jamun could produce wine of acceptable quality.

The processing variables tested in the present experiment had resulted in production of an acidic pungent unacceptable beverage from jamun, which could be denoted as vinegary, which means a wine with "the harsh aroma of vinegar" usually resulting from the presence of acetic acid (Chakraborti *et al.*, 2014)). Reduction of active primary fermentation period to about 10 days as against the 21 days tested in the present experiment would have resulted in production of a quality wine from jamun.

Success of any value added product depends on its final acceptance by the consumers. No food or beverage is worth producing, distributing or marketing without having an approximate idea that its sensory quality is accepted by consumers (Boulton, 1980). Hence sensory evaluation plays a significant role in quality control and marketing of the products. The successful sensory evaluation in food industries is achieved by linking sensory properties to physical and chemical quality parameters, formulation and process variables which enables manufacturing food products with maximum consumer acceptance. It is frequently used in food industries for new product development and recipe modification of the products. It is carried out to find out differences among the products, nature of difference and possible acceptance or rejection of products on the basis of differences. Sensory evaluation is categorized into objective, where hedonic response of a product is determined by skilled evaluators whereas in subjective testing, consumers are involved in the evaluation process. Hedonic assessment is the economical and ideal method to find out the influence of variations in ingredients, manufacturing, wrapping, or shelf life (Sharif et al., 2017). As a single wine had not shown high scores for all the quality parameters during hedonic scoring, the overall acceptability score of each wine was calculated. As the objective of the present experiment was to prepare a quality wine, the wine with high antioxidant potential having a high overall acceptability was selected from each fruit.

When overall acceptability was assessed, the highest mean score (6.1) was obtained for the carambola wine prepared using 1:2 fruit: water ratio, 0.75% yeast and clarified by pectinase (Fig.2.). The above wine was brilliant, had 4.6^0 TSS, 0.5% acidity, 8.9% alcohol, 183.63 mgg^{-1} polyphenol and the highest antioxidant activity of 64.9 % (Fig.3.)., hence selected for storage study.

The highest mean score for overall acceptability (4.7) was obtained for the papaya wine prepared using 1:2 fruit: water ratio, 0.75% yeast and clarified by pectinase (Fig.4.). This wine had high antioxidant activity (66.88%) and lower polyphenol content (181.91mgg^{-1}). This was closely followed by the wine (4.6) prepared using the same method but with 1% yeast, which had the highest antioxidant activity and high polyphenol content. The above selected wine was brilliant, had 3^0 TSS, 0.46% acidity, 6.15% alcohol, 201.57 mgg^{-1} polyphenol and 79.46 % antioxidant activity (Fig.5.).

The rose apple juice diluted to 1:2 ratio ameliorated to 20^0B with cane sugar having yeast inoculum of 0.75% and clarified by settling gave a better quality wine with the highest mean score for overall acceptability (5.4) (Fig.6.).. The above wine

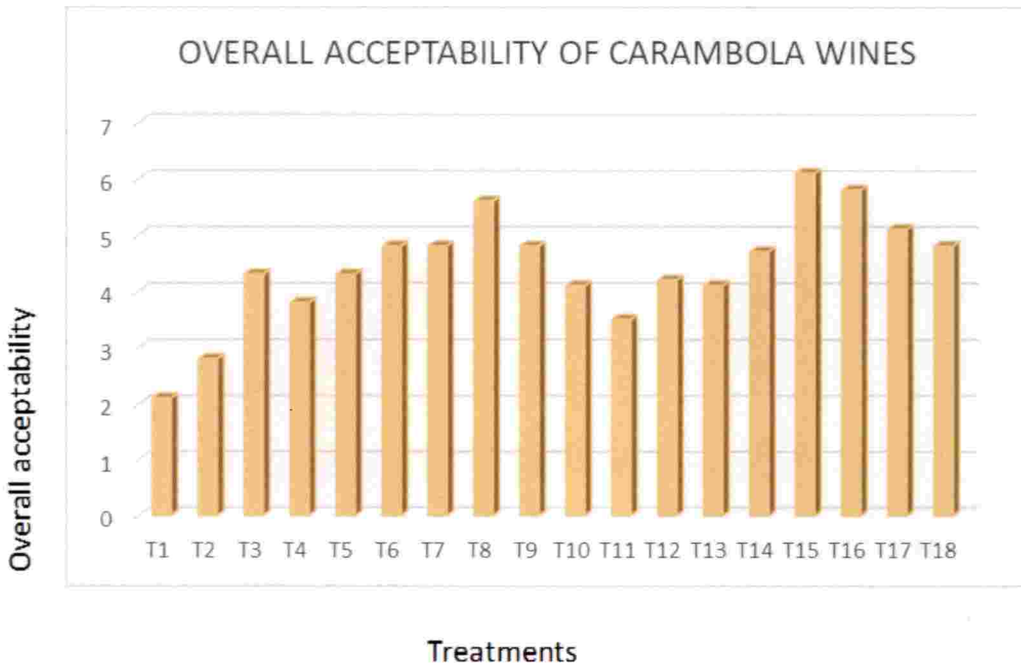


Figure.2. Overall acceptability of carambola wines

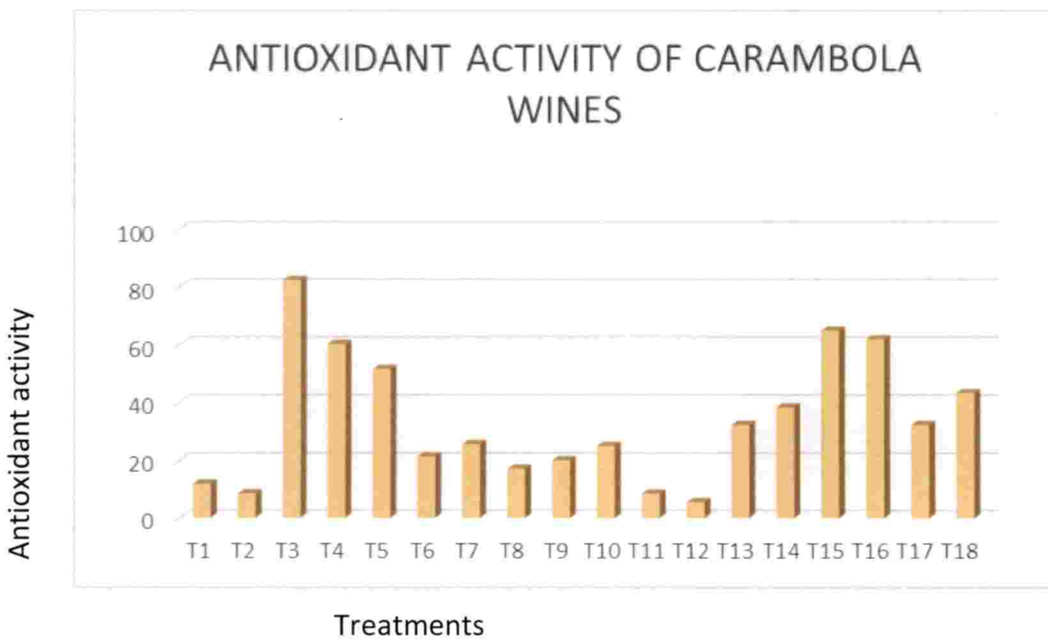


Figure.3. Antioxidant activity of carambola wines

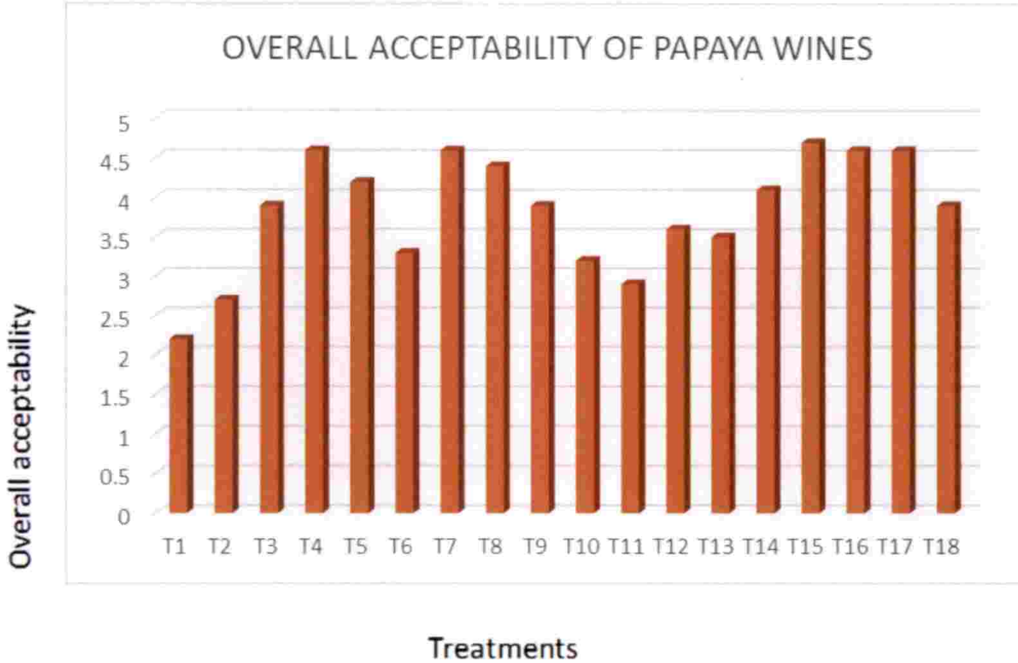


Figure.4. Overall acceptability of papaya wines

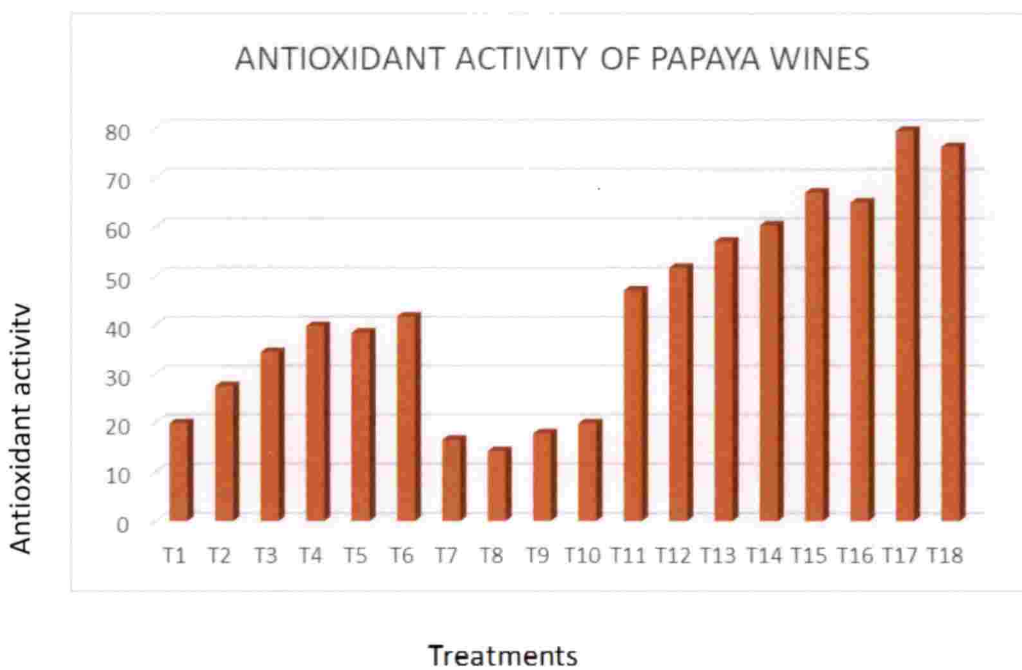


Figure.5. Antioxidant activity of papaya wines

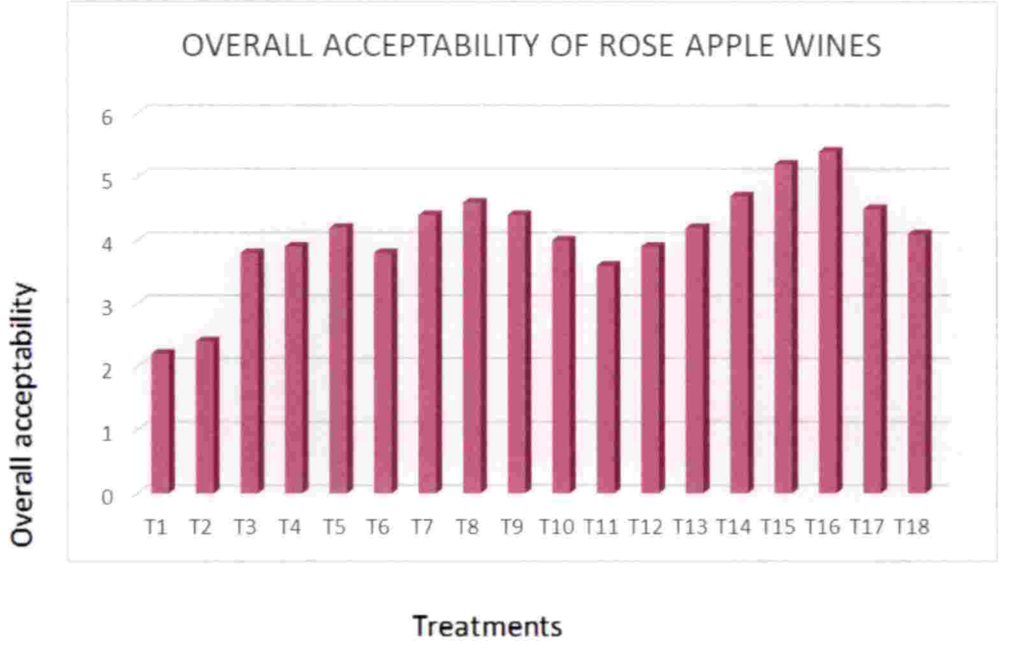


Figure.6. Overall acceptability of rose apple wine

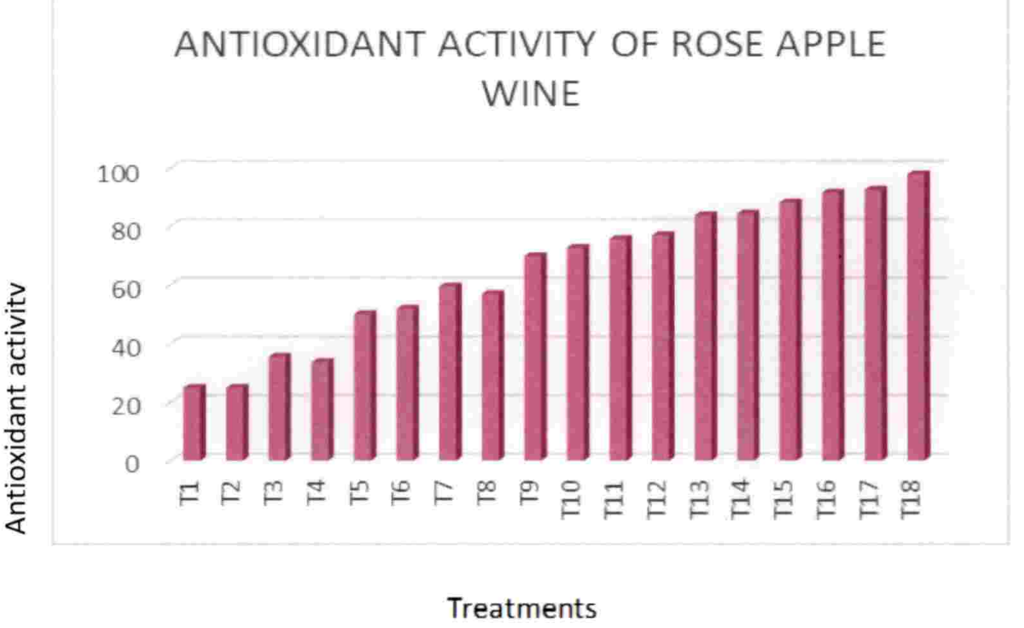


Figure.7. Antioxidant activity of rose apple wines

was brilliant, had 5.6^0 brix TSS, 0.44% acidity, 9.08% alcohol, 97.79 mgg^{-1} polyphenol and the highest antioxidant activity of 91.56 %, hence selected for storage trials (Fig.7.)

Sensory parameters of the selected wines are expressed in the form of spider plot (Fig 8a-8c).

In general, wines prepared from must of 1: 2 fruit: water ratio had superior quality and acceptability (Plate 7a-7c.). The highest antioxidant activity was reported in all the wines prepared from a fruit: water ratio of 1:2. Thick pulp and high acidity of fruits affect their fermentation and hence the quality of the final product (Shukla et al., 1991). Rate of fermentation is reported to increase with increase in dilution level due to the better fermentation conditions in the must such as initial aerobic conditions needed for the yeast growth and optimum pH as a result of dilution of thick pulp. Jamun must prepared by 1:2 dilution gave better fermentation behaviour. With the increase in dilution level, TSS, titratable acidity and sugar content decreased (Joshy et al., 2012).

Appearance along with clarity or brilliancy is a good indicator of wine quality and the yeast has important role in fermentation of fruits and fruit wine quality. The brilliance of a wine is a direct result of the wine style and the way the wine was made, filtered and bottled, and is not a characteristic of the varietal. Yeasts, especially, different strains of *S. cerevisiae*, have long been used for the production of alcoholic beverages. Addition of 0.5% yeast was not sufficient for providing quality wines. When yeast concentration was increased to 0.75%, the brilliancy (Plate 8a-8c.) and acceptability of the wines increased. The higher yeast count helped in faster fermentation as suggested by Chaudhary *et al.* (2017). But when the concentration was further increased to 1%, cloudiness enhanced resulting in reduced acceptability. The interaction of inoculum level, fermentation time and temperature was found to be significant in influencing the wine quality (Borate et al. , 2008).

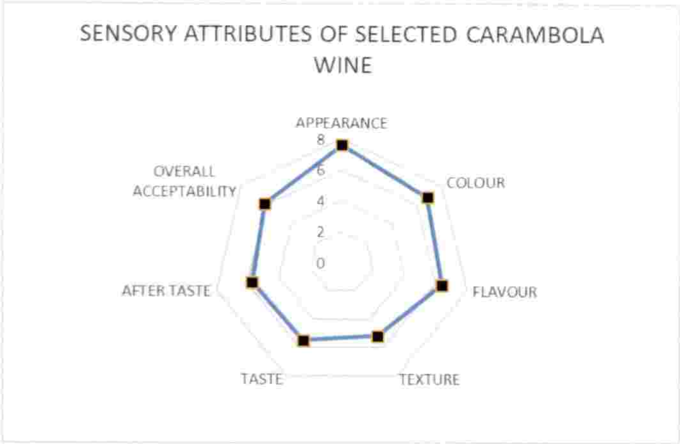


Figure. 8 (a)

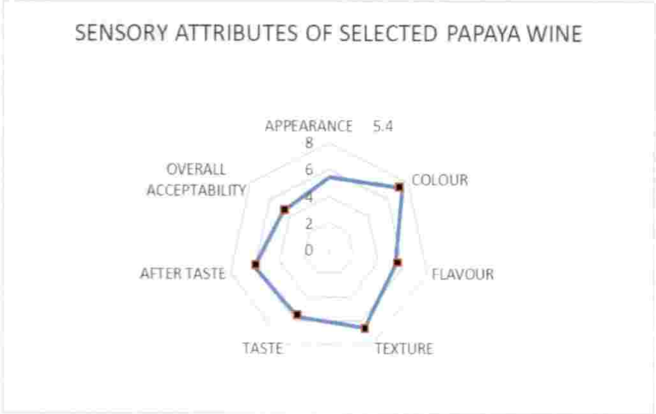


Figure. 8 (b)

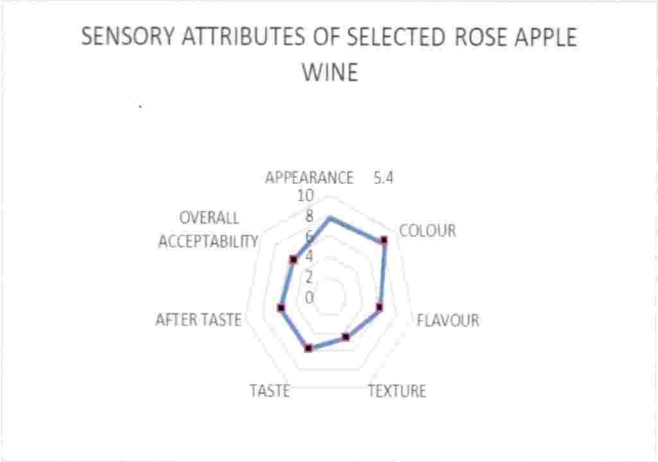


Figure. 8 (c)

Figure. 8 (a-c) Spider plot representing sensory attributes of selected wines

7(a) Carambola

7(b) Papaya

7(c) Rose apple

Plate.7(a-c). Effect of Fruit : Water ratio on quality of fruit wines

8(a) Carambola

8(b) Papaya

8(c) Rose apple

Plate.8(a-c) Effect of Yeast Concentration on Quality of fruit wines

Enzymes are natural and fundamental elements in the winemaking process. Although they occur naturally in wine grapes and yeast, commercial enzymes are commonly added in production of fruit wines. They can be used to improve extraction and the aromatic profile of a wine, while also accelerating the winemaking process. Use of pectinase enzyme was essential for clarifying papaya and carambola wines (Plate 9a-9b.). Thick pulp of papaya and flesh in carambola could be efficiently clarified by use of pectinase enzyme. Pectinase caused cloudy particles to aggregate into larger units that deposited as sediment. Pectinase helps in hydrolysis of plant cell wall polysaccharides, improvement of skin maceration and colour extraction, quality, stability and filtration of wines. Clarification by settling could give a brilliant quality wine from rose apple, which was juicy or watery in nature (Plate 9c).

5.4. STORAGE POTENTIAL OF FRUIT WINES

The best wine selected from each fruit was stored under ambient condition for a period of three months in two different packaging materials viz., plain and amber coloured glass bottles for analysing the storage stability. Quality parameters viz., polyphenol and alcohol content of the best wine were analysed initially and during the first and third month of storage.

The polyphenol content of all the three (Carambola, papaya and rose apple) wines decreased during aging (Fig 9a-9c.) as stated in literature (Ivanova et al., 2011). Decreased phenolic content is presumably a result of oxidation of phenolic compounds and their degradation leading to changes of their content by loss of reactive hydroxyl groups (Singleton et al., 1999). In addition, a formation of protein-tannin complexes has also been shown to contribute towards a decrease in phenolic content (Betes- Saura et al., 1996) of white wine.

9(a) Carambola

9(b) Papaya

9(c) Rose apple

Plate.9(a-c). Effect of clarification methods on fruit wines

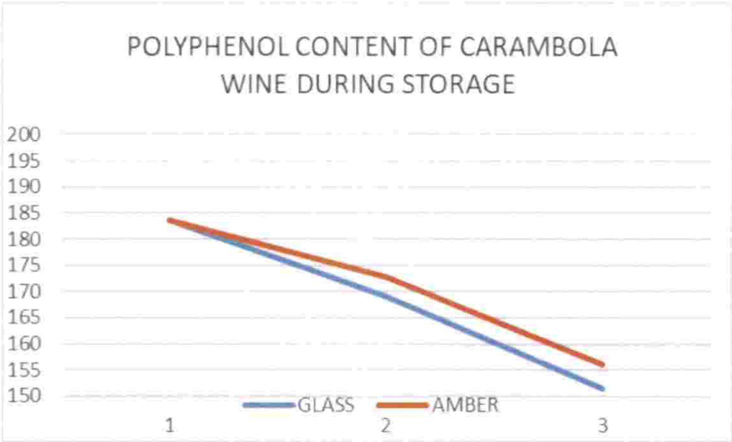


Figure. 9 (a)

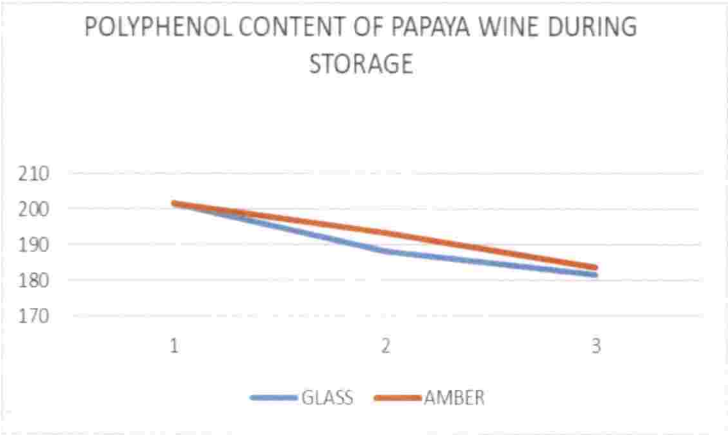


Figure. 9 (b)

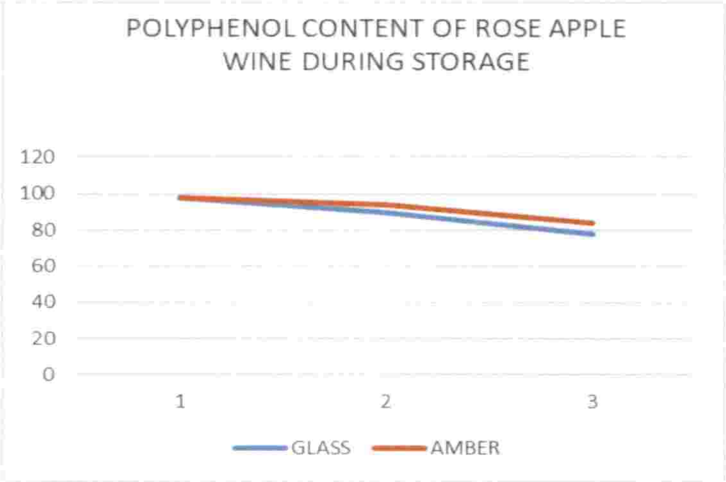


Figure. 9 (b)

Figure. 9 (a-c). Polyphenol content of fruit wines during storage

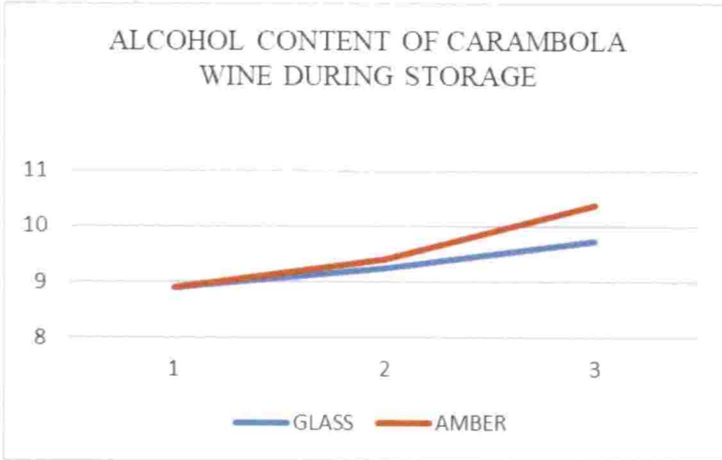


Figure. 10 (a)

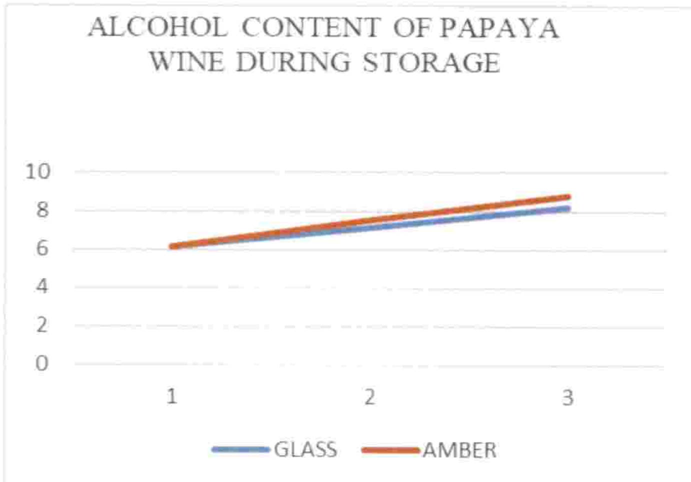


Figure. 10 (b)

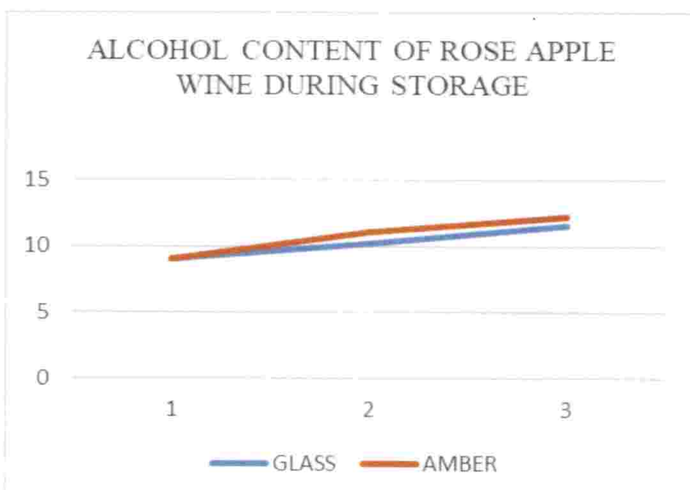


Figure.10 (c)

Figure. 10 (a-c). Alcohol content of wines during storage

The alcohol content of all wines increased during storage in both type of containers (Fig 10a-10c.). Similar increase in alcohol content was reported in sweet lovi-lovi wines during three months of storage (Sebastian,2017). The alcohol percent of the grape wine increased as a result of decrease in total soluble sugars due to the activity of yeast during fermentation (Chikkasubbanna *et al.* ,1990).

Wine is a commodity that can improve in flavour and value with age, but it can also rapidly deteriorate if kept in inadequate conditions. It is a very sensitive and complex combination of chemical components. The percentage reduction in polyphenol content was observed to be less and increase in alcohol content was high in amber containers after storage. Retention of quality parameters were more in amber coloured bottles. Jones and Davis (2000) reported storage conditions as one of the factors influencing the wine quality.

Storage conditions viz., light and humidity including wine packaging and storage temperature are the most significant factors that have the most direct impact on a wine's quality. Direct sunlight through plain glass bottles can adversely react with phenolic compounds in wine and create "wine faults". Amber coloured bottles prevent wines from sunlight and oxidation thus preserving antioxidants and its polyphenols. During the storage period, temperature, bottle position, oxygen content and light may affect the qualitative characteristics of aroma, colour and phenolic composition (Chira et al., 2012).

There was no significant difference between the microbial load of wines stored in different bottles or recorded during different storage periods.

The wines standardised from carambola and papaya were light wines whereas rose apple produced a medium wine with 12.01% alcohol under the tested wine producing conditions. As per FSSAI the prepared papaya wine could be classified as a low alcoholic beverage as it contains less than 8% alcohol. Light wine contains 7-

9% alcohol and medium wine contains 9-16% alcohol (Singh and Singh, 2006). Singleton et.al. (1965) reported that an acceptable wine should contain a minimum alcohol concentration of 8% by volume, which was satisfied by the selected carambola and rose apple wines. Fruit wines usually have an alcohol content ranging between 5 and 13% (Joshi et.al., 2012). The variation in alcohol content of wines prepared from different fruits was due to variation in the sugar levels of treatments. The more the sugar present in the fermenting juice the higher is the yield of ethyl alcohol. As the initial TSS was maintained at 20^0 brix, which included all the soluble solids present in the must, the other wine making conditions would have influenced the alcohol percent in the final product.

The present study highlighted the fermentation capabilities of three different neglected and underutilized fruits of Kerala. These underutilized and surplus fruits can be fully exploited for wine production at the grass root level and value addition substantially reduces the cost of the farmers and increases their profit. Pande and Akoh (2010) reported that wine could be prepared from nutritionally diverse, highly perishable, underutilized tropical fruits, thereby helping efforts to increase shelf life by reducing post-harvest and production losses, improve nutritional value of fruits, increase cultivation and commercialization of fruits as well as to generate profits to growers and the existing wine industry.

The initial sugar concentration, addition of enzyme, yeast strains, fruit dilution and wine making technology and synergistic effect of these factors are some of the major factors affecting wine quality. The difference in wine quality obtained in the present experiment might be due to the difference in quality of raw material used and the conditions maintained during the experiment. Adoption of a 1:1:1 fruit: sugar: water ratio as in grape wine production might not help in quality wine production from underexploited fruits, rich in polyphenol content. Instead, maintenance of an intial TSS level above 20^0 brix and adjustment of pH of the must would have produced wines of superior quality and acceptability. The quality especially sugar and acidity level of the raw material should be checked and sufficient amount of granulated sugar should be added to produce required alcohol and sugar content in the finished product. The study clearly proved that the wine making conditions should be formulated for different raw materials based on their initial quality parameters.

Summary

6. SUMMARY

The present investigation entitled "Standardization of quality wine production from selected underexploited fruits" was conducted at Department of Post Harvest Technology, Kerala Agricultural University, College of Agriculture, Vellayani, Thiruvananthapuram, during the year 2017-2019 with the objective to standardize quality wine production technology from selected under exploited fruits of Kerala.

Fruit wines were prepared from four different under exploited fruits viz., carambola, papaya, jamun and rose apple independently by varying three process parameters viz., fruit water ratio, yeast concentration and clarification methods. Fruit water ratio was tried at 1:0.75, 1:1 and 1:2; yeast concentration at 0.5, 0.75 and 1% and clarification by pectinase enzyme and by settling, thus forming 18 different fruit wines in each fruit.

The experiment was conducted as four continuous steps viz., fruit wine preparation, quality analysis of fruit wines, selection of the best fruit wine and studying the storage potential of fruit wines. The major findings are summarized as follows.

Carambola

Carambola (*Averrhoa carambola*) could be converted to wines with a fermented yield of 63.8 to 138.8%. Colour of the carambola wine was observed to be golden yellow; they were brilliant (sparkling clear) to cloudy and had a predominant astringent taste compared to fruity taste.

There was no significant difference between the TSS and acidity content of different wines. Sugars (Total sugars and reducing sugars) were absent in all the prepared carambola wines; hence belonged to dry wines.

The alcohol content of the carambola wines ranged from 7.2 to 12.3% indicating that they belonged to light or medium wines.

The highest alcohol content was observed when the wine was prepared using 1:2 fruit water ratio, 1% yeast and clarified using pectinase (12.3%) and by settling (11.6%). This wine was on par with the wine which was produced in the same manner, but with 0.5 % yeast (12 %).

Wines recorded the least polyphenol (169.40 mgg^{-1}) content when fruit water ratio was maintained at 1:2 ratio, yeast concentration of 0.5% and clarification done by pectinase. This wine was on par with the wine which was prepared in the same manner, but with 0.75% yeast (183.63 mgg^{-1}).

Antioxidant activity was highest (82.4%) when the wine was prepared with 1: 0.75 fruit water ratio, 0.75% yeast and clarified using pectinase, but it had least sensory score for flavour (2.2) and very low scores for other sensory quality parameters. The wines produced using 1:2 fruit water ratio, and 1% yeast and clarified using pectinase had highest score (6.0) for taste and the one clarified by settling had highest score for after taste (5.8). But these wines had low antioxidant activity. The wine prepared using 1:0.75 fruit water ratio, 1% yeast and clarified by settling had the highest mean score for appearance (8.5) and colour (8.4), but with low antioxidant activity (21.5%).

The antioxidant activity was high (64.9%) and polyphenol content was low (183.63 mgg^{-1}) when the wine was prepared using 1:2 fruit water ratio, 0.75% yeast and pectinase as clarifying agent and it had highest score for texture (5.2) and comparatively high scores for all other sensory attributes. The results clearly showed that a single wine had no superior scores for all sensory quality parameter.

Papaya

Papaya (*Carica papaya)* could be processed into wines with light yellowish colour, characteristic papaya odour and a fermented yield of 20.6 to 86%.

No significant difference was noticed between the TSS and acidity content of different papaya wines. Both total and reducing sugars were absent in all the papaya wines produced, indicating that they are dry in nature.

The alcohol content of the papaya wine ranged from 6.15 to 17.28%. Alcohol content was highest when the papaya wine was prepared using 1:1 fruit water ratio, 0.75% yeast and clarified by settling which was on par with wine produced in the same manner but clarified using pectinase (16.36%). The wines produced using 1:2 fruit water ratio with 1% yeast and 1:0.75 fruit water ratio with 0.5% yeast both clarified using pectinase had the least alcohol content of 6.15%.

The wine prepared using 1:2 fruit water ratio, 0.75% yeast and pectinase had high antioxidant activity (66.88%), lower polyphenol content ($181.91 mgg^{-1}$) and highest ranks for appearance (7.1), colour (7.9) and flavour (8.2).

When yeast concentration was increased to 1% , must was prepared in 1:2 ratio and clarification was done using pectinase, the resultant wine had highest antioxidant activity (79.46%), high polyphenol content ($181.91 mgg^{-1}$), highest mean score for after taste (6.0) and a higher score for taste (5.7).

Jamun

The drink that was prepared from jamun *(Syzygium cumini*) had a dark purple attractive colour with a very high acidity range from 0.69 to 5.42% resulting in pungent smell and vinegary taste.

There was no significant difference between the TSS content of the drink and the alcohol content ranged from 6.44 to 24 %. By the completion of 42 days, the ethyl alcohol might have undergone acetic fermentation resulting in the production of acetic acid. The polyphenol content ranged from 5.81 to 37.26 $mgg^{-1}$and the antioxidant activity ranged from 11.92 % to 24.83%.

Since the product prepared from jamun had a very high acidity and pungent taste, it could not be subjected to sensory analysis and further storage studies.

Rose Apple

Rose apple (*Syzygium aqueum*) could be processed into light pinkish colored brilliant wines with a fermented yield of 52.8 to 134.%

Assessment of the chemical quality parameters of the rose apple wines showed no significant difference between the TSS content of different wines. Acidity content of the rose apple wines ranged from 0.28 to 0.69%.

Wine prepared using 1:2 fruit water ratio, 0.75% yeast and clarified by settling had the highest mean score for color (8.3), after taste (5.8) and second highest mean score for taste (5.8) and the acidity content was also lower compared to other wines (0.44%).

All the rose apple wines lacked sugar content and the alcohol content varied from 5.27% to 12.01%.

The lowest alcohol content was recorded in wines prepared using 1:1 fruit water ratio, 1% yeast and clarified by settling. The highest alcohol content was observed in wines prepared from 1:2 fruit water ratio, 0.75% yeast and clarified using pectinase.

Polyphenol content of rose apple wines was highest in the wines prepared using 1:2 fruit water ratio, 1% yeast, irrespective of clarification methods and the lowest polyphenol content was recorded in the wine prepared using 1:0.75 fruit water ratio, 0.5% yeast and clarified by settling.

The wine prepared using 1:2 fruit water ratio, 1% Yeast and clarified by settling had highest antioxidant activity (97.81%), high polyphenol content (108.80 mgg^{-1}) and low sensory scores for flavour (4.6), after taste (5.0), appearance (4.3), and colour (3.1).

Preparation of wine with 1:2 Fruit water ratio, 1% yeast and pectinase as a clarifying agent, resulted in wine with high antioxidant activity (92.50%), high polyphenol content (110.37 mgg^{-1}) and very low score for taste (4.7) and after taste (5). Wines prepared using 1:2 fruit water ratio, 0.75% yeast and clarified by settling had higher antioxidant activity (91.56%), lower polyphenol content (97.79 mgg^{-1}) and highest sensory score for appearance (7.7), colour (8.3) and after taste (5.8).

The lowest antioxidant activity was observed in the wines prepared using 1:0.75 fruit water ratio and 0.5% yeast, irrespective of clarification methods.

As a single wine had not shown high scores for all the quality parameters during hedonic scoring, the overall acceptability score of carambola, papaya and rose apple wine was calculated. As the objective of the experiment was to prepare a quality wine, the wine with high antioxidant potential having a high overall acceptability was selected from each fruit.

When overall acceptability was assessed, the highest mean score (6.1) was obtained for the carambola wine prepared using 1:2 fruit water ratio, 0.75% yeast and clarified by pectinase. The above wine was brilliant, had 4.6^0 TSS, 0.5% acidity, 8.9% alcohol, 183.63 mgg^{-1} polyphenol and the highest antioxidant activity of 64.9 %, hence selected for storage study.

The highest mean score for overall acceptability (4.7) was obtained for the papaya wine prepared using 1:2 fruit water ratio, 0.75% yeast and clarified by pectinase. This wine had high antioxidant activity (66.88%) and lower polyphenol content (181.91mgg^{-1}). This was closely followed by the wine (4.6) prepared using the same method but with 1% yeast, which had the highest antioxidant activity and high polyphenol content. The above selected wine was brilliant, had 3^0 TSS, 0.46% acidity, 6.15% alcohol, 201.57 mgg^{-1} polyphenol and 79.46 % antioxidant activity.

The highest mean score overall acceptability (5.4) was obtained for the rose apple wine prepared using 1:2 fruit water ratio, 0.75% yeast and clarified by settling. The above wine was brilliant, had 5.6^0 brix TSS, 0.44% acidity, 9.08% alcohol, 97.79 mgg^{-1} polyphenol and the highest antioxidant activity of 91.56 %.

In general, wines prepared from must of 1: 2 fruit water ratio had superior quality acceptability and highest antioxidant activity.

Addition of 0.5% yeast was not sufficient for providing quality wines. When yeast concentration was increased to 0.75%, the brilliancy and acceptability of the wines increased. But when the concentration was further increased to 1%, cloudiness enhanced resulting in reduced acceptability.

Use of pectinase enzyme was essential for clarifying papaya and carambola wines whereas clarification by settling could give a brilliant quality wine from rose apple.

The best wine selected from each fruit was stored under ambient condition for a period of three months in two different packaging materials viz., plain and amber coloured glass bottles for analysing the storage stability.

The polyphenol content of all the three (Carambola, papaya and rose apple) wines decreased and the alcohol content of wines increased during storage in both the containers.

The percentage reduction in polyphenol content was less and increase in alcohol content was high in amber containers after storage indicating better quality retention in amber coloured bottles.

There was no significant difference between the microbial load of wines stored in different bottles or recorded during different storage periods.

The wines prepared from carambola and papaya were light wines where as rose apple produced a medium wine with 12.01% alcohol under the tested wine producing conditions.

The present study highlighted the fermentation capabilities of three different underutilized fruits of Kerala.

But maintenance of a higher initial TSS level instead of 20^0 brix and adjustment of pH of the must would have produced wines of superior quality and acceptability. The study clearly proved that the wine making conditions should be formulated for different raw materials based on the initial quality parameters.

References

7. REFERENCES

Abu-Amsha, R., Croft, K. D., Puddey, I. B., Proudfoot, J. M., and Beilin, L. J. 1996. Phenolic content of various beverages determines the extent of inhibition of human serum and low density lipoprotein oxidation *in vitro*: Identification and mechanism of action of some cinnamic acid derivatives from red wine. *Clin. Sci.* 91: 449-458.

Akingbala, J. O., Oguntimein, G. B., Olunlade, B. A., and Aina, J. O. 1994. Effects of pasteurization and packaging on properties of wine from over-ripe mango (Mangifera indica) and banana (Musa acuminata) juices. Tropical Sci. 41(3): 45-47.

Akubor, P. I., Obio, S. O., Nwadomere, K. A., and Obiomah, E. 2003. Production and quality evaluation of banana wine. Plant Foods Hum. Nutr. 58(3): 1-6.

Amerine, M. A., Berg, H. W., and Cruess, W. V. 1967. *The Technology of Wine Making* (3rd Ed). AVI, Westport, Connecticut, pp. 76.

Amerine, M. A., Kunkee, R., Ough, K. C. S., Singleton, V. L., and Webb, A. D. 1980. *The Technology of Wine Making* (4th Ed). AVI, Westport, Connecticut, pp. 185-703.

Amerine, M. A. and Ough, C. S. 1980. Methods for Analysis of Musts and Wines. Wiley Publishing, 663p.

Awe, S. 2011. Production and microbiology of pawpaw (*Carica papaya* L.) wine. *Curr. Res. J. Biol. Sci.* 3(5): 443-447.

Ayanru, D. K. G., Sharma, V. C., Ogbeide, O. N., and Okiy, D. A. 1985. Effects of the quality and type of micro-organisms on ethanol production from pawpaw. Energy 10(9): 1009-1016.

Badola, H. K. and Aitken, S. 2010. Biological resources and poverty alleviation in the Indian Himalayas. *Biodivers.* 11(3-4); 8-18.

Balaswamy, K., Rao, P. P. G., Nagender, A., and Akula, S. 2011. Preparation of sour grape (*Vitis Vinifera*) beverages and evaluation of their storage stability. *J. Food Process Technol.* 2(3): 105-109.

Berry, C. J. J. 2000. *First Steps in Wine Making*. GW Kent, Inc. 3667 Morgan Road, 235p.

Betés-Saura, C., Andrés-Lacueva, C., and Lamuela-Raventós, R. M. 1996. Phenolics in white free run juices and wines from Penedès by high-performance liquid chromatography: Changes during vinification. *J. Agric. Food Chem.* 44(10): 3040-3046.

Bhaskar, B. and Shantaram, M. 2013. Morphological and biochemical characteristics of averrhoa fruits. *Int. J. Pharma. Chem. Biol. Sci*. 3(3): 924-928.

Bhowmick, N. 2011. Some lesser known minor fruit crops of northern parts of West Bengal. In: Sheikh, M. K. (Ed.), *Proceedings of Second IS on Pomegranate and Minor including Mediterranean Fruits*, *Acta Horticulturae*. pp. 61-63.

Bisson, L. F. and Butzkc, C. E. 2007. *History of Wine Making*. WINE, Microsoft R Encarta, 123p.

Blandino, A., Al-Aseeri, M. E., Pandiella, S. S., Cantero, D., and Webb, C. 2003. Cereal-based fermented foods and beverages. *Food Res. Int.* 36(6): 527-543.

Blois, M. S. 1956. Antioxidant determinations by the use of a stable free radical. *Nat*. 29: 1199-2000.

Bolarin, F. M., Olotu, F. B., and Onyemeize, U.C. 2016. Rose apple fruit: It prospects for juice and wine production. *Eur. J. Educ. Dev. Psychol*. 4(2): 25-32.

Borate, S. R., Kotecha, P. M., and Chavan, J. K. 2008. Standardization of wine making technology from Jamun juice. *Beverage Food World* 35(11): 42-43.

Boulton, R. 1980. The relationships between total acidity, titratable acidity and pH in wine. *Am. J. Enol. Viticulture* 31(1): 76-80.

Budak, N. H. 2017. Bioactive components of Prunus avium L. black gold (red cherry) and Prunus avium L. stark gold (white cherry) juices, wines and vinegars. J. Food Sci. Technol. 54(1): 62-70.

Caoli, M. A. and Magsino, R. F. 2017. Acceptability of Kamias (Averrhoa bilimbi) wine. Asia Pacific J. Multidisciplinary Res. 5(2): 64-66.

Carluccio, M. A., Siculella, L., Ancora, M. A., Massaro, M., Scoditti, E., Storelli, C., Visioli, F., Distante, A., and de Caterina, R. 2003. Olive oil and red wine antioxidant polyphenols inhibit endothelial activation: Antiatherogenic properties of Mediterranean diet phytochemicals. *Arteriosclerosis Thrombosis Vascular Biol.* 23(4): 622-629.

Chakraborty, K., Saha, J., Raychaudhuri, U., and Chakraborty, R. 2014. Tropical fruit wines: A mini review. *Nat. Products Ind. J.* 10(7): 219-228.

Chinjirakul, K., Wang, S. Y., and Iripanich, J. 2007. Natural volatile treatments increase free-radical scavenging capacity of strawberries and blackberries. *J. Sci. Food Agric.* 87: 1463-1472.

Chaudhary, C., Yadav, B. S., and Grewal, R. B. 2014. Preparation of red wine by blending of grape (*Vitis vinifera* L.) and jamun (*Syzygium cuminii* L. Skeels) juices before fermentation. *Int. J. Agric. Food Sci. Technol.* 5(4): 239-348.

Chaudhary, C., Khatak, A., Devi, R., Rai, D., and Yadav, B. S. 2017. Study of fermentation variables for the preparation of wine from jamun fruit. *J. Pure Appl. Microbiol.* 11(3): 1623-1631.

Chikkasubbanna, V., Chandha, K. L., and Ethiraj, S. 1990. Influence of maturity of Thomson seedless grapes on the wine corporation and quality. *Indian J. Hortic.* 47: 12-17.

Chira, K. 2012. Cabernet sauvignon red wine astringency quality control by tannin characterization and polymerization during storage. *Eur. Food Res. Technol.* 234(2): 253-261.

Choudhary, M., Singh, D., and Shukla, A. K. 2006. Opportunities of product diversification of underutilized fruits of arid region. In: Abstracts, National Symposium on Underutilized Horticultural Crops; 8-9June, 2006, Bangalore. Indian Institute of Horticultural Research, Bangalore, p.62. Abstract No. 90.

Chowdhury, P. and Ray, R. C. 2007. Fermentation of Jamun (*Syzgium cumini* L.) fruits to form red wine. *ASEAN Food J.* 14(1): 15-23.

Chung, H. J. 2008. Effect of vibration and storage on some physico-chemical properties of a commercial red wine. *J. Food Composition Anal.* 21: 655-659.

Das, J. N. 2009. Studies on storage stability of jamun beverages. *Indian J. Hortic.* 66(4): 508-510.

Das, A., Raychaudhuri, U., and Chakraborty, R. 2012. Cereal based functional food of Indian subcontinent: A review. *J. Food Sci. Technol.* 49(6): 665-672.

Erten, H., Tanguler, H., Cabaroglu, T., and Canbas, A. 2006. The influence of inoculum level on fermentation and flavour compounds of white wines made from cv. Emir. J. Inst. Brewing 112(3): 232-236.

Esteves, M. A. and Orgaz, M. M. 2001. The influence of climatic variability on the quality of wine. *Int. J. Biometeorol.* 45(1): 13-21.

Fang, F. 2008. Effects of grape variety, harvest date, fermentation vessel and wine ageing on flavonoid concentration in red wines. *Food Res. Int.* 41: 53-60

Frankel, E. N., Waterhouse, A. L., and Yeissedre, P. L. 1995. Principal phenolic phytochemicals in selected California wines and their antioxidant activity in inhibiting oxidation of human low-density lipoproteins. *J. Agric. Food Chem.* 43: 890-894.

Gaikwad, R. S., Thorat, S. S., and Kotecha, P. M. 2016. Preparation of wine from jamun fruits (*Syzygium cumini* L). *Bioinfolet.* 13(2): 332- 335.

Gebauer, J., El-Siddig, K., El Tahir, B. A., Salih, A. A., Ebert, G., and Hammer, K. 2007. Exploiting the potential of indigenous fruit trees: Grewia tenax (Forssk.) Fiori in Sudan. Genetic Resour. Crop Evol. 54(8): 1701-1708.

Ghosh, P., Pradhan, R. C., Mishra, S., Patel, A. S., and Kar, A. 2017. Physicochemical and nutritional characterization of jamun (*Syzygium cuminii*). *Curr. Res. Nutr. Food Sci. J.* 5(1): 25-35.

Grant-Preece, P. 2017. Light-induced changes in bottled white wine and underlying photochemical mechanisms. *Crit. Rev. Food Sci. Nutr.* 57(4): 743-754.

Gumienna, M., Lasik, M., and Czarnecki, Z. 2011. Bioconversion of grape and chokeberry wine polyphenols during simulated gastrointestinal *in-vitro* digestion. *Int. J. Food Sci. Nutr.* 62(3): 226-233.

Hajizadeh, H. S. and Kazemi, M. 2012. Investigation on approaches to preserve post harvest quality and safety in fresh cut fruits and vegetables. *Res. J. Environ. Sci.* 6(3): 93-106.

Hale, M. D., Mccafferty, K., Larmie, E., Newton, J., and Swan, J. S. 1999. The influence of oak seasoning and toasting parameters on the composition and quality of wine. *Am. J. Enol. Viticulture* 50(4): 495-502.

Halliwell, B. 1996. Antioxidants in human health and disease. *Annual Rev. Nutr.* 16: 33-50.

Hazarika, T. K. 2014. Underexploited and lesser known fruits of Mizoram. In: *Future Crops*. (2^{nd} Ed.). Daya Publishing House, New Delhi, pp. 85-102.

Heinonen, I. M., Lehtonen, P. J., and Hopia, A. I. 1998. Antioxidant activity of berry and fruit wines and liquors. *J. Agric. Food Chem.* 46: 25-31.

Hiremath, S. M., Nagaraju, H. R., and Gowda, D. S. M. 2006. Processing, value addition and marketing of underutilized fruit-a case study. In: Abstracts, National Symposium on Underutilized Horticultural Crops; 8-9 June, 2006, Bangalore. Indian Institute of Horticultural Research, Bangalore, p.62. Abstract No. 91.

Ivanova, V., Vojnoski, B., and Stefova, M. 2011. Effect of the winemaking practices and aging on phenolic content of Smederevka and Chardonnay wines. Food Bioprocess Technol. 4(8): 1512-1518.

Ivanova, V., Vojnoski, B., and Stefova, M. 2012. Effect of winemaking treatment and wine aging on phenolic content in Vranec wines. *J. Food Sci. Technol.* 49(2): 161-172.

Jackson, D. I. and Lombard, P. B. 1993. Environmental and management practices affecting grape composition and wine quality- A review. *Am. J. Enology Viticulture* 44(4): 409-430.

Jackson, R. S. 2000. *Principles, Wine Practice Science Perception*. Academic Press, California, USA, pp. 283-427.

Jones, G. V. and Davis, R. E. 2000. Climate influences on grapevine phenology, grape composition, and wine production and quality for Bordeaux, France. *Am. J. Enology Viticulture* 51(3): 249-261.

Jongen, W. 2002. Fruit and vegetable processing: Improving quality [On-line]. Available: https://books.google.co.in/books?id=JqjAgAAQBAJ&printsec=frontcover&source=gbsge_summary_r&cad=0#v=onepage&q&f=false [12 Jan. 2019].

Joshi, V. K., Sharma, S., and Devi, M. P. 2009. Influence of different yeast strains on fermentation behaviour, physico-chemical and sensory qualities of plum wine. *Nat. Product Radiance.* 8(4): 445-451.

Joshi, V., Rao, B. S., and Reddy, R. S. 2012. Studies on the physico-chemical properties of wine in different varieties of grapes. *Asian J. Hortic.* 8(1): 174-178.

Joshi, V. K., Sharma, R., Girdher, A., and Abrol, G. S. 2012. Effect of dilution and maturation on physico chemical and sensory quality of jamun (black plum) wine. *Indian. J. Nat. Products. Resour.* 3(2): 222-227.

Joshi, V. K., John, S., and Abrol, G. S. 2013. Effect of addition of herbal extract and maturation on apple wine. *Int. J. Food Fermentation Technol.* 3(2):107-109.

Joy, T. 2003. Utilization of underexploited fruits for product development. M.Sc. (Home Science) thesis, Kerala Agricultural University, Thrissur, 121p.

Kallithraka, S., Salacha, M. I., and Tzourou, I. 2009. Changes in phenolic composition and antioxidant activity of white wine during bottle storage: Accelerated browning test versus bottle storage. Food Chem. 113(2): 500-505.

Kelebek, H. and Selli, S. 2011. Evaluation of chemical constituents and antioxidant activity of sweet cherry (*Prunus avium* L.) cultivars. *Int. J. Food Sci. Technol.* 46(12): 2530-2537.

Kotecha, M. P., Adsule, R. N., and Kadam, S. S. 1994. Preparation of wine from over-ripe banana fruits. Beverage Food World 21: 28-29.

Kruijssen, F., Keizer, M., and Giuliani, A. 2009. Collective action for small-scale producers of agricultural biodiversity products. Food Policy 34(1): 46-52.

Kumar, V., Jnawali, P., Goud, P. V., and Bhasin, J. K. 2016. Effect of maturation on physico-chemical and sensory quality characteristics of custard apple wine. *Cogent Food Agric*. 2: 1-8.

Kumoro, A. C., Rianasari, D., Pinandita, A. P. P., Retnowati, D. S., and Budiyati, C. S. 2012. Preparation of wine from jackfruit (*Artocarpus heterophyllus* lam) juice using baker yeast: Effect of yeast and initial sugar concentrations. *World Appl. Sci. J.* 16(9): 1262-1268.

Kundu, B. S., Bardiya, M. C., and Tauro, P. 1976. Studies on fruit wines: Banana wine. *Haryana J. Hortic. Sci*. 5: 160-163.

Lakshmana, D., Rehiman, A. B., and Lingaiah, H. B. 2006. Effect of quality of must on quality of carambola wine. *Karnataka J. Agric. Sci.*19(2): 352-356.

Landbo, A. K. and Meyer, A. S. 2001. Ascorbic acid improves the antioxidant activity of European grape juices to inhibit peroxidation of human LDL *in vitro*. *Int. J. Food Sci. Technol.* 36: 727-736.

Lewis, D. and Grocizam, M. 1989. The cultivation and utilization of carambola in surinam. *Proc. Interamer. Soc. Trop. Hort.* 33: 596-599.

Lum, E. 1998. The Home Winemakers Manual [On-line]. Available: http://www.erowid.org/chemicals/alcohol/alcohol_article2_winemakers_manual.pdf [17 Apr. 2019].

Maragatham, C. and Panneerselvam, A. 2011. Effect of different stages of ripening of fruit on papaya wine using *Saccharomyces cerevisiae*. *Int. J. Biotechnol. Biochem.* 7(2): 305-310.

Mintel. 2009. The fruit juice market: An appealing squeeze [On-line]. Available: http://www.marketresearchworld.net/index.pp?opion=com-content&task=view&i d=484&Ttemid=48 [20 Sept. 2018].

Mohan, S., Nair, P. R., and Long, A. J. 2007. An assessment of ecological diversity in homegardens: A case study from Kerala State, India. *J. Sustain. Agric.* 29(4): 135-153.

Mohanty, S., Ray, P., Swain, M. R., and Ray, R. C. 2006. Fermentation of cashew (Anacardium occidentale L.) "apple" into wine. J. Food Processing Preservation 30(3): 314-322.

Mudnic, I., Budimir, D., Modun, D., Gunjaca, G., Generalic, I., Skroza, D., Katalinic, V., Ljubenkov, I., and Boban, M. 2012. Antioxidant and vasodilatory effects of blackberry and grape wines. *J. Med. Food* 15(3): 315-321.

Musyimi, S. M., Sila, D. N., Okoth, E. M., Onyango, C. A., and Mathooko, F. M. 2013. The influence of process optimization on the fermentation profile of mango wine prepared from the Apple mango variety. J. Anim. Plant Sci. 17(3): 2600-2607.

Napahde, S., Durve, A., Bharati, D., and Chandra, N. 2010. Wine production from carambola (*Averrhoa carambola*) juice using *Saccharomyces cerevisiae. Asian J. Exp. Biol. Sci.* 1:20-23.

Narain, N., Bora, P. S., Holschuh, H. J., and Vasconcelos, M. A. 2001. Physical and chemical composition of carambola fruit (*Averrhoa carambola* L.) at three stages of maturity. *Cienc. Technol. Aliment.* 3(3): 144-148.

Obaedo, M. E. and Ikenebomeh, M. J. 2009. Microbiology and production of banana (Musa sapientum) wine. Niger. J. Microbiol. 23(1): 1886-1891.

Özkan, A., Gübbük, H., Güneş, E., and Erdoğan, A. 2011. Antioxidant capacity of juice from different papaya (*Carica papaya* L.) cultivars grown under greenhouse conditions in Turkey. *Turkish J. Biol.* 35(5): 619-625.

Panda, S. K., Sahu, U. C., Behera, S. K., and Ray, R. C. 2014. Bio-processing of bael [*Aegle marmelos* L.] fruits into wine with antioxidants. *Food Biosci.* 5: 34-41.

Pande, G. and Akoh, C. C. 2010. Organic acids, antioxidant capacity, phenolic content and lipid characterisation of Georgia-grown underutilized fruit crops. *Food Chem.* 120(4): 1067-1075.

Paul, S. K. and Sahu, J. K. 2014. Process optimization and quality analysis of Carambola (*Averrhoa carambola* L.) wine. *Int. J. Food Eng.* 10(3): 457-465.

Peter, K. V. and Abraham, Z. 2007. Biodiversity in Horticultural Crops. Daya Books, New Delhi, 345p.

Pinhero, R. G. and Paliyath, G. 2001. Antioxidant and calmodulin-inhibitory activities of phenolic components in fruit wines and its biotechnological implications. *Food Biotechnol.* 15: 179-192.

Rana, A. and Singh, H. P. 2013. Bio-utilization of wild berries for preparation of high valued herbal wines. *Indian. J. Nat. Products. Resour.* 4(2): 165-169.

Ranganna, S. 1986. *Handbook of Analysis and Quality Control for Fruit and Vegetable Products*. Tata McGrw – Hill Publishing company Limited, New Delhi, 182p.

Reddy, L. V. A. and Reddy, O. V. S. 2005. Production and characterization of wine from mango fruit (*Mangifera indica* L). *World J. Microbiol. Biotechnol.* 21(8-9): 1345-1350.

Renaud, S. and de Lorgeril, M. 1992. Wine, alcohol, platelets and the french paradox for coronary heart disease. *Lancet*. 339: 15-23.

Revi, M. 2014. Effect of packaging material on enological parameters and volatile compounds of dry white wine. Food Chem. 152: 331-339.

Ribéreau-Gayon, P., Dubourdieu, D., Doneche, B., and Lonvaud, A. 2000. Biochemistry of alcoholic fermentation and metabolic pathways of wine yeasts. *Handbook Enol* 1: 51-74.

Rivero-Pérez, M. D., Muniz, P., and González-Sanjosé, M. L. 2008. Contribution of anthocyanin fraction to the antioxidant properties of wine. *Food Chem. Toxicol.* 46(8): 2815-2822.

Robertson, G. L. 2006. *Food packaging: Principles and Practice* (2nd Ed). Boca Raton, FL, CRC Press, 203p.

Robinson, J. and Harding, J. 2015. *The Oxford Companion to Wine*. American Chemical Society, 192p.

Ross, I. A. 1999. *Medicinal Plants of the World Humana Press*. New Jersey, pp. 25-63.

Sabat, S., Chaitra, L. N., and Ranjitha, R. 2016. Evaluation of antioxidant and antimicrobial activity of wine from various sources. *Int. J. Curr. Microbiol. Appl. Sci.* 5(3): 26-35.

Sadasivam, S. and Manikam, A. 1992. *Biochemical Method for Agricultural Sciences.* Wiley Eastern Limited and Tamil Nadu Agricultural University, Coimbatore, 246p.

Sandhu, D. K. and Joshi, V. K. 1995. Technology, quality and scope of fruit wines especially apple beverages. *Indian Food Ind.* 14: 24-24.

Saranraj, P., Sivasakthivelan, P., and Suganthi, K. 2017. Baker's Yeast: Historical development, genetic characteristics, biochemistry, fermentation and downstream processing. J. Acad. Ind. Res. 6: 111-119.

Scrimgeour, N. 2015. Exploring the effect of elevated storage temperature on wine composition. *Australian J. Grape Wine Res.* 21(1): 713-722.

Sebastian, K. 2017. Post harvest characterization and value addition of sweet lovi-lovi (*Flacourtia* spp). M.Sc.(Hort) thesis, Kerala Agricultural University, Thrissur. 110p.

Sevda, S., Khartmol, P., and Rodrigues, L. 2011. Studies in preparation of banana wine (fruit wine) [On-line]. Available: http://core.kmi.open.ac.uk/download/ pdf/289899.pdf [30 Apr .2019].

Shamrez, A., Shukla, R. N., and Mishra, A. 2013. Study on drying and quality characteristics of tray and microwave dried guava slices. Intl. J. Sci. Eng Technol. 3(4): 2348-4098

Sharif, M. K., Masoos, S. B., Hafiz, R. S. and Muhammmad, N. 2017. *Sensory Evaluation and Consumer Acceptability*. University of Agriculture, Faisalabad, 92p.

Sharma, S. and Joshi, V. K. 2003. Effect of maturation on the physico-chemical and sensory quality of strawberry wine. J. Sci. Ind. Res. 62: 601-608.

Sharma, O. P. and Bhat, T. K. 2009. DPPH antioxidant assay revisited. *Food Chem.* 113: 1202-1205.

Shukla, K. G. and Revis, B. 1985. Enological qualities of some orange cultivars grown in Garhwal hills. J. Food Sci. Technology 22(1): 72-73.

Shukla, K. G., Joshi, M. C., Yadav, S., and Bisht, N. S. 1991. Jambal wine making-Standardization of a methodology and screening of cultivars. J. Food Sci. Technol. 28(3): 142-144.

Simenthy, T. 2015. Proximate analysis and product development in nutmeg (*Myristica fragrans* Houtt.) rind. M.Sc.(Hort) thesis, Kerala Agricultural University, Thrissur, 91p.

Singh, P. K. and Singh, K. I. 2006. Traditional alcoholic beverage, Yu of Meitei communities of Manipur. *Indian J. Traditional Knowl.* 5(2): 184-190.

Singleton, V. L., Orthofer, R., and Lamuela-Raventós, R. M. 1999. Analysis of total phenols and other oxidation substrates and antioxidants by means of folin-ciocalteu reagent. In: *Methods in Enzymology*. Academic press, pp. 152-178.

Singleton, V. L., Rossi, J. A., Amerine, M. A., and Ough, C. C. 1965. *Methods for Analysis of Wines and Musts.* Wiley and Sons, New York, 176p.

Sun, J., Chu, Y. F., Wu, X., and Liu, R. H. 2015. Antioxidant and antiproliferative activities of common fruits. *J. Agric. Food Chem.* 50(3): 7449-7454.

Swami, S. B., Thakor, N. J., and Divate, A. D. 2014. Fruit wine production: A review. *J. Food Res. Technol.* 2(3): 93-100.

Tandon, D. K. and Kumar, S. 2006. Potentiality of underexploited fruits for value addition. In: Abstracts, National Symposium on Underutilized Horticultural Crops; 8-9 June 2006. Indian Institute of Horticultural Research, Bangalore, p.15. Abstract No. 11.

Tsai, P. J., Huang, H. P., And Huang, T. C. 2004. Relationship between anthocyanin patterns and antioxidant capacity in mulberry wine during storage. J. Food Quality 27(6): 497-505.

Tuorila, H. and Monteleone, E. 2009. Sensory food science in the changing society: Opportunities, needs, and challenges. Trends Food Sci. Technol. 20(2): 54-62.

Umeh, S. O., Udemezue, O., Okeke, B. C., and Agu, G. C. 2015. Paw paw (*Carica papaya*) wine: With low sugar produced using saccharomyces cerevisiae isolated from a local drink ''burukutu''. *Int. J. Biotechnol. Food Sci.* 5(2): 17-22.

Valim, F. D. P., Aguiar-Oliveira, E., Kamimura, E. S., Alves, V. D., and Maldonado, R. R. 2016. Production of star fruit alcoholic fermented beverage. *Indian J. Microbiol.* 56(4): 476-481.

Wall, M. M. 2006. Ascorbic acid, vitamin A, and mineral composition of banana (*Musa* sp.) and papaya (*Carica papaya*) cultivars grown in Hawaii. *J. Food Composition Anal.* 19(5): 434-445.

Wang, C., Liu, Y., Jia, J., Sivakumar, T. R., Fan, T., and Gui, Z. 2013. Optimization of fermentation process for preparation of mulberry fruit wine by response surface methodology. *Afr. J. Micrbiol. Res.* 7(3): 227-236.

Ward, O. P. and Ray, R. C. 2006. Microbial biotechnology in horticulture-An overview. In: Microbial Biotechnology in Horticulture, Vol. 1, CRC Press, pp. 15-27.

Wildenradt, H. L. and Singleton, V. L. 1974. The production of aldehydes as a result of oxidation of polyphenolic compounds and its relation to wine aging. Am. J. Enol. Viticulture 25(2): 119-126.

Yao, L. H., Jiang, Y. M., Shi, J., Toma, F. A, S-Barbera, N., Datta, N., Singanusong and Chen, S. S. 2004. Flavonoids in food and their health benefits. *Plant Foods Hum. Nutr.* 59: 113-122.

Yoo, K. M., Al-Farsi, M., Lee, H., Yoon, H., and Lee, C. Y. 2010. Antiproliferative effects of cherry juice and wine in Chinese hamster lung fibroblast cells and their phenolic constituents and antioxidant activities. *Food Chem.* 123: 734–740.

Appendices

Score card for organoleptic evaluation of fruit wines

Characteristics	Scores								
	1	2	3	4	5	6	7	8	9
Appearance									
Colour									
Flavour									
Texture									
Odour									
Taste									
After taste									
Overall acceptability									

9 point Hedonic scale

Like extremely : 9 points

Like very much : 8 points

Like moderately : 7 points

Like slightly : 6 points

Neither like nor dislike : 5 points

Dislike slightly : 4 points

Dislike moderately : 3 points

Dislike very much : 2 points

Dislike exrtremely : 1 points

Name :

Signature :

Date :

Abstract

STANDARDIZATION OF QUALITY WINE PRODUCTION FROM SELECTED UNDEREXPLOITED FRUITS.

by

KEERTHANA DAS

(2017-12-032)

ABSTRACT

Submitted in partial fulfillment of the

requirements for the degree of

MASTER OF SCIENCE IN HORTICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF POST HARVEST TECHNOLOGY

COLLEGE OF AGRICULTURE

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KERALA, INDIA

2019

ABSTRACT

The study entitled “Standardization of quality wine production from selected underexploited fruits” was conducted at Department of Post Harvest Technology, College of Agriculture, Vellayani, Thiruvananthapuram, during the year 2017-2019 with the objective to standardize quality wine production technology from selected underexploited fruits of Kerala.

Fruit wines were prepared from four different underexploited fruits *viz*., carambola, papaya, jamun and rose apple independently by varying three process parameters *viz*., fruit: water ratio, yeast concentration and clarification methods. Fruit: water ratio was tried at 1:0.75, 1:1 and 1:2; yeast concentration at 0.5, 0.75 and 1% and clarification by pectinase enzyme and by settling, thus formed 18 different wines in each fruit. The experiment was conducted as four continuous steps *viz*., production of fruit wines, quality evaluation, selection of the best wine and studying the storage potential of wines.

Among the four underexploited fruits, carambola, papaya and rose apple produced wines of acceptable quality. No significant difference was noticed in the TSS content of different wines. All the prepared wines were “dry” due to absence of residual sugar content.

Carambola wines were golden yellow, brilliant to cloudy with a predominant astringent taste and 7.2 to 12.3% alcohol content. Papaya wines were light yellowish with a characteristic papaya odour and their alcohol content ranged from 6.15 to 17.28%, whereas rose apple wines were light pinkish, brilliant with 5.27% to 12.01% alcohol.

The wine with high antioxidant potential and high overall acceptability was selected from each fruit for conducting storage trials. The highest mean overall acceptability score (6.1) was obtained for the carambola wine prepared using 1:2

fruit: water ratio, 0.75% yeast and clarified by pectinase. This wine was brilliant, had 4.6^{0} TSS, 0.5% acidity, 8.9% alcohol, 183.63 mgg^{-1} polyphenol and the highest antioxidant activity (64.9 %).

Papaya wine prepared using 1:2 fruit: water ratio, 1% yeast and clarified by pectinase had the highest antioxidant activity and high polyphenol content with an overall acceptability score of 4.6. This brilliant wine had 3^{0} TSS, 0.46% acidity, 6.15% alcohol, 201.57 mgg^{-1} polyphenol and 79.46 % antioxidant activity.

The highest mean overall acceptability score (5.4) was obtained for the rose apple wine prepared using 1:2 fruit: water ratio, 0.75% yeast and clarified by settling. It was brilliant, with 5.6^{0} B, 0.44% acidity, 9.08% alcohol, 97.79 mgg^{-1} polyphenol and the highest antioxidant activity (91.56 %).

The processing variables tried in the present experiment resulted in a dark purple attractive but unacceptable beverage from jamun with high alcohol (6.44 to 24 %) and acidity (0.69 to 5.42%), pungent smell and vinegary taste; hence could not be subjected to sensory analysis and further storage studies.

In general, wines prepared from 1: 2 fruit: water ratio had superior quality, acceptability and highest antioxidant activity. Addition of 0.5% yeast was not sufficient for producing quality wines. When yeast concentration was increased to 0.75%, the brilliancy and acceptability of the wines increased and at 1%, cloudiness enhanced resulting in reduced acceptability. Use of pectinase enzyme was essential for clarifying papaya and carambola wines where as clarification by settling could give a brilliant quality wine from rose apple.

The best wine selected from each fruit was stored under ambient condition for a period of three months in plain and amber coloured glass bottles for analysing their storage stability. The polyphenol content of the wines decreased during storage in both the containers and the percentage reduction was less in amber containers indicating better retention of quality parameters. The alcohol content increased during storage and the percentage increase was more in amber containers. There was no significant difference in the microbial load of wines stored in different bottles or different storage periods.

The present study highlighted the fermentation capabilities of three underutilized fruits of Kerala and standardized quality wine production from them. It was proved that the wine processing parameters should be formulated for different raw materials based on their initial characteristics for production of acceptable quality wines.