TECHNOLOGY REFINEMENT FOR WINE PRODUCTION FROM UNDER EXPLOITED FRUITS

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(2019-12-029)

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KERALA, INDIA

2021

TECHNOLOGY REFINEMENT FOR WINE PRODUCTION FROM UNDER EXPLOITED FRUITS

by

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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

VELLAYANI, THIRUVANANTHAPURAM-695522

KERALA, INDIA

2021

DECLARATION

I, hereby declare that this thesis entitled **"TECHNOLOGY REFINEMENT FOR WINE PRODUCTION FROM UNDER EXPLOITED 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, associateship, fellowship or other similar title, of any other University or Society.

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Certified that this thesis entitled **"TECHNOLOGY REFINEMENT FOR WINE PRODUCTION FROM UNDER EXPLOITED FRUITS"** is a record of bonafide research work done independently by **Ms. Aiswarya S. (2019-12-029)** 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.

I would like to express my deepest gratitude and personal thankfullness to my chairperson ***Dr. Mini C****, Professor and Head, Department of Post Harvest Technology, for her valuable guidance, persistent help and co-operation .Thank you mam for your unconditional love and special care. Without her constant support and patience, my PG research would not have been possible. Words may fall in short to express my sincere and profound gratitude to her.*

With great pleasure, I express my heartfelt gratitude to ***Ms. Athulya S Kumar****, Assistant professor, Dept. of Post Harvest Technology, for her timely advice, valuable suggestions, care and support at all the stages of my research work. I thank her for her wholehearted help throughout my venture.*

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 humbly express my sincere gratitude to ***Dr. Chitra N.,*** *Assistant Professor, AINP-SBB, Dept. of Agricultural Microbiology, for her explicit instructions, valuable suggestions and friendly approach in the pursuit of the work.*

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

I am thankful to ***Suja chechi, Rejitha chechi, Lekshmi chechi, Bindhu chechi and Shaji chettan*** *for their love, timely support and assistance during the lab work. I avail this opportunity to thank my dear seniors* ***Aparna Chechi, Athira chechi, Greeshma chechi, Archana chechi, Swathi chechi, Keerthana chechi, Aparna chichi, Elso chechi and Gayathri chechi*** *for their support, help, care, love and encouragement during my research work.*

I am really thankful to my batch mates ***Pavi, Paathu and Sree*** *for the love, care, patience and support throughout these two years and the way they spent their valuable time for helping me.*

Words are inadequate to express my thanks to my beloved friends ***Krishna, Kavya, Navya, Anu, Akhi, Sheela, Maasha and Arun*** *for their constant support, care, positive energy and unconditional love that I have received in all my tough and good moments.*

I find special pleasure in expressing whole hearted thanks to ***Subha teacher and family*** *and my dear friends* ***Anju George, Anupama chechi, Elizabeth chechi and Deepthi chechi*** *for their persistent help and support. I profoundly express my gratefulness to my dear juniors,* ***Gayathri and Hiba*** *for their support and love.*

Mere words cannot express my profound indebtedness to my ***Achan, Amma, Ettan and Achu*** *for their unconditional love, sacrifices and support bestowed on me during my hard periods. The loving prayers of my family members have always helped me from beginning to end of my research work.*

I express my love and gratitude to my new family my caring husband ***Arjunettan, Amma, Anju chechi and Rejin Chettan*** *for their support.*

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.*

Finally, I thank all those who extended help and support to me in one way or another in the successful completion of this thesis work.

AISWARYA S

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LIST OF ABBREVIATIONS

°C	Degree celsius
%	Per cent
mL	Millilitre
L	Litre
ppm	Parts per million
CD	Critical difference
T	treatments
CRD	Completely Randomized Design
et al.	And other co workers
Fig.	Figure
g	Gram
kg	Kilogram
mg	Milligram
°B	Degree brix
viz.	Namely
NS	Non-significant
TSS	Total Soluble Solids
NaOH	Sodium hydroxide

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Introduction

1. INTRODUCTION

India enjoys an eminent position on under exploited, under utilized or neglected fruit crops of the world. The diverse geographical conditions favour for growing a wide variety of fruit crops, which are available in plenty and also in different seasons. Most of the under exploited fruits of the tropics are often available only in the local markets and are practically unknown to other parts of the world. A large number of these fruits can grow under adverse conditions and are also known for their therapeutic and nutritive value and can satisfy the demands of the health-conscious consumers. Many tropical underutilized fruits are rich in vitamins, minerals, fibres and have an important role to play in satisfying the demand for nutritious, delicately flavoured and attractive natural foods of high therapeutic value. Today, consumers are becoming increasingly conscious of the health and nutritional aspects of their food basket. The tendency is to avoid chemicals and synthetic foods and preference is for nutrition through natural resources. The underutilized fruits like bael, jamun, karonda, carambola, aonla, phalsa, garcinia, tamarind, wood apple etc. are the main sources of livelihood for the poor and they play an important role in overcoming the problems of malnutrition. However, some of these fruits are not acceptable in the market in fresh form due to their acidic and astringent taste. The reasons for lack of popularity of these fruits may be due to a variety of reasons including ignorance, lack of knowledge, availability, difficulty in harvesting and storage. Hence, there is a need to concentrate on research efforts in diversification and popularization of such underutilized fruit crops. This can be achieved to some extent through processing and value addition.

Food processing is the process of treating and handling food in such a way so as to stop or greatly slow down spoilage while maintaining nutritional security, texture and organoleptic quality as well as increasing its shelf life. There is great scope for processing and value addition of the underutilized fruits into various products like jam, jelly, preserve, candy, confectionery, pickle, fruit drinks, dried products etc.

The quality of wine is dependent on type of substrate, sugar content, strain of yeast, climatic and storage conditions. Fruit wines are fermented alcoholic beverages made from a variety of base ingredients and can be made from virtually any plant matter that can be fermented. The fruits used in winemaking are fermented using yeast and aged in wood barrels to improve the taste and flavour quality. The technology of manufacturing wine from grape, pineapple, banana and cashew apple is quite advanced, however limited information is available on the preparation of wine from other under exploited fruits commonly seen or wasted in our homesteads. Therefore, winemaking from such fruits is considered as an alternative for utilizing surplus and overripe fruits for generating additional revenues for the fruit growers.

Research studies conducted in the Department of Post Harvest Technology has proved the necessity of selection of wine processing parameters based on the quality of raw materials used (Das, 2019). Govt. of Kerala had recently permitted production of low alcoholic beverages by the processing units; the specifications prescribed in "Direction under section 16(5) of Food safety and standards Act, regarding implementation of low alcoholic beverage standards regulation, 2018" does not match with the prevailing accepted homescale technology of wine production. These differences necessitated the refinement of existing technology of wine production by analyzing the quality parameters and acceptance of products developed by various techniques/ specifications. Hence this present study entitled "Technology refinement for wine production from under exploited fruits" was undertaken with an objective to assess the quality parameters of wines prepared in three different methods from selected underexploited fruits of Kerala *viz*., jamun, papaya and rose apple.

Review of literature

2. REVIEW OF LITERATURE

India enjoys a prominent position in the production of the fruit crops that remain underexploited for many reasons. Adapted to adverse environmental conditions, these fruit crops are well known for their therapeutic and nutritive value and can satisfy the growing demands of the health-conscious consumers. Focused attention and innovative technologies should be researched and incorporated for the improvement and utilization of these underutilized fruit crops in an effective manner. With an intense diversification of value added products, a vivid product portfolio can be developed from underutilized fruits retaining their nutritional and medicinal properties. Fruit wines are one among the important value added products that can be formulated from the underutilized fruits. The present chapter reviews the available literature on fruit wines from under exploited fruits, physical, chemical and sensory characters and antioxidant properties of wines from grape as well as other fruits, factors influencing quality of fruit wines and storage stability parameters of fruit wines.

2.1. Wines

Wine is one among the oldest, fermented, traditional, convenient alcoholic beverages of the mankind (Das *et al*., 2012). Wines made from fruits are often named after the fruits from which they are prepared. No other beverage, other than water and milk, has gained worldwide acceptance and respect in every age like wine (Swami *et al*., 2014).

Wine is considered an important supplement to human diet, as it enhances satisfaction and provides much-needed relaxation in the digestion and absorption of food (Joshi *et al*., 2017). Wine can be prepared from a wide range of fruits, and the only criteria for its production is that the amount of sugar present should be enough to get converted into alcohol during the fermentation process. Fermentation is a viable technique in developing new products with adapted physicochemical and sensory qualities, especially flavour and nutritional components. Alcoholic fermentation is one among the most ancient human’s technologies and now it is one of the most commercially prosperous biotechnological processes (Saranraj *et al*., 2017).

Alcohol is a macronutrient in wines and it act as an energy source, that has a capability for providing calories for all biological activities (Bisson *et al*., 1995). Sweetness of wine is determined by the combination of many factors, including the amount of sugar in the wine, but also the levels associated with alcohol, acids and tannins (Jackson, 2000).

Wine contains water, alcohol, acids, sugars, amino acids, pigments, esters, vitamins, carbohydrates, minerals, acids flavouring compounds and tannins that provide medicinal and therapeutic value (Patil *et al*., 2005). The wine has almost essence and composition of most of the important bioactive components and nutrients present in the original fruit juice (Joshi *et al*., 2009). The quality of the wine is dependent on type of substrate, sugar content, strain of yeast, climatic and storage conditions (Vazhacharickal *et al*., 2016).

2.2. Wines from under-exploited fruits

Fruit wines are alcoholic beverages made from grapes or other fruits such as peaches, plums or apricots, bananas, elderberry or black current etc. which are nutritious and tasty (Swami *et al*., 2014). Due to high acid content of cherries, raspberries, strawberries and pineapples, these are used to produce a very sour tasting wine (Saranraj *et al*., 2017).

Carvalho (2001) reported that wine prepared from cashew apple variety Madakkathara-1 was best in its overall acceptability and flavour. Blended wines developed by mixing cashew apple wine with banana, pineapple and grape wines were found to best. Ezeronye (2004) reported cashew apple as the best fruit which is suited for wine production in the tropics commercially. Ward and Ray (2006) and Mohanty *et al*. (2006) reported suitability of jackfruit and cashew apple for wine production, due to their availability, taste, high sugar, flavour, water contents and overall chemical structure.

The mineral composition of palm wine is special as it contains potassium, calcium, magnesium, sodium, iron, sulfur, phosphorus, phenol, glucose, pectin (Okafor, 2007). Depending on the level of nutritional composition of soursop juice, the ability to support yeast growth, high alcohol content and the taste of wine, *Annona muricata* is an excellent source of wine production (Okigbo and Obire, 2008).

According to Rahman and Islam (2021), sour and over-ripened mulberry fruits can be converted into wine which has a sweet and sour taste. Jamun fruit can be used to make an acceptable dry wine and a high-quality alcoholic beverage (Joshi *et al*., 2012b).

Jackfruit wine can be prepared from jackfruit juice with potential health benefits due to their good antioxidant properties (Jagtap *et al*., 2011). The fermentation of jackfruit wine was completed on the 14th day itself, with a high alcohol content of 18%. The wine also has excellent antioxidant activity and the final product gives off a pleasant aroma, enhancing its sensory properties (Sharma *et al*., 2013).

Processing of star fruit wine allows the utilization of low quality fruits that cannot be marketed, enhancing the value of the product thereby leading to preparation of value added product (Aye *et al*., 2014). According to Das (2019) carambola, papaya and rose apple wines were prepared with 1:2 fruit: water ratio and had the highest antioxidant acitivity, overall acceptability and superior quality.

Combined sugarcane juice with high sugar and watermelon juice with high antioxidant properties can be used to prepare wine with acceptable, desirable colour and health benefits (Helen *et al*., 2016). Sugarcane juice combined with fruits was a promising substance for wine production, as it is a source of sucrose (carbon), phenolic compounds, and flavonoids (Patil *et al*., 2021).

Anu (2008) found that pink watery rose apple, white watery rose apple and malay apple with 1:1:0.5 fruit: sugar: water ratio is ideal for wine preparation. Bolarin *et al*. (2016) reported that rose apple fruit can be used as a good raw material for making rose apple wine.

Banana is suitable for wine production because of their high sugar content (Robinson, 2006). Sevda *et al*. (2011) observed that banana juice produced good quality wine with higher yield of 5% alcohol after fermentation of nine days. Samson

(2015) found that banana waste wine was excellent quality than banana wine and the pineapple fruit and waste wines were also found as best on both phyto-chemical and sensory characters. According to Kiribhaga et al. (2020), banana wine is a delicious alcoholic beverage with low alcohol content.

Pineapples are suitable for wine making because of having enchanted nutritional benefits and that contains good sugar proportion (Adaikan and Adebiyi, 2004). Peach fruit has less acid than plum or apricot, but its pulp must be diluted with water to make it a sweet wine (Joshi *et al*., 2005a).

Gaharwar *et al*. (2020) reported that sapota fruit is a good source of 12 to 18% sugar which has a great ability to convert it into alcohol and thus thrive in the post harvest industry for preparing fermented products such as wine.

2.3. Physical characteristics of wines

The rate of fermentation was observed to be higher at initial stage which further declined at a later stage on account of the production of more alcohol in wines (Joshi and Sharma, 1995).

According to Attri (2009), the fermentation rate and fermentation efficiency were decreased with an increase in initial sugar concentration in cashew apple wine.

Custard apple wine of 1: 4 dilution with di ammonium hydrogen phosphate resulted highest rate of fermentation (1.32 °B/24 hours). The maximum fermentation efficiency was found in 1:3 dilution with di ammonium hydrogen phosphate (88.05 %) irrespective of dilutions, addition of di ammonium hydrogen phosphate increased the rate of fermentation (Vikas *et al*., 2011).

Joshi *et al*. (2012b) reported that jamun wine prepared by dilution of 1:2 gave better fermentation behaviour than 1:0.5 and 1:1 dilutions.

2.4. Chemical characteristics of wines

Teotia *et al*. (1991) reported that muskmelon (*C. melo*) wine with alcohol content of 6.5% (w/v) exhibited a very good sensory quality. Akingbala *et al*. (1994) reported that the alcohol content ranged from 5 to 13% in mango wine

Akingbala *et al*. (1994) reported that banana wine had a pH of 3.85 and alcohol content of 13.98%. Kotecha *et al*. (1994) reported that banana wine had a reducing sugar and tannin content of 3.18% and 0.044% respectively.

Highest antioxidant activity was demonstrated in wine prepared from a mixture of black currants and bilberries and of black and red currants. Single wines made of mixtures of black currants and crowberries (98% inhibition), cranberries (92%), rowanberries and apple (90%), apples (84%), and cowberries and birch sap (69%) were efficient as antioxidants (Heinonen *et al*., 1998a).

Berries and fruits contain a wide range of flavonoids and other phenolic compounds that possess antioxidant activity. Fruits with different colours influenced the total phenolic content of fruit wines. It was found that bilberries with a strong purple colour had higher phenolic contents (Heinonen *et al*., 1998b).

Acidity plays an important role in determining wine quality by assisting the fermentation and enhancing the overall characteristics. Poor fermentation occurs due to lack of acidity (Berry, 2000).

High hydroxyl radical scavenging efficiency was demonstrated by blueberry wines than blackberry and red grape wines (Pinhero and Paliyath, 2001). Sun *et al*. (2002) reported that different winemaking techniques such as a prolonged extraction time could be a credible description for the high phenolic content in fruit wines, such as blackcurrant wine.

Akubor *et al*. (2003) while studying the production and quality of banana wine found that the total soluble solids decreased and titratable acidity increased with the increasing length of fermentation of the juice.

Ezeronye (2004) reported that pineapple wine produced using yeast (*Saccharomyces cerevisiae* (OW-11)) isolated from palm wine had the highest alcohol content of 12.2% compared to pawpaw, cashew, and mango wine with alcohol content 12%, 10.8%, and 10.6% respectively.

The qualitative changes in banana pulp and juice during the winemaking process were studied by Shanmugasundaram *et al*. (2005). They found that there was a reduction in TSS content of wine prepared from the pulp of Poovan, Rasthali and Robusta varieties from 23°Brix for 8.0, 6.9, and 5.4°Brix respectively during fermentation of 28 days; whereas, the wine produced from the juice of these varieties showed decrease up to 6.5, 4.5, and 3.9 °Brix.

The total phenolic contents of different fruit wines from the highest to the lowest value are in the order from blackberry >bilberry >black mulberry >sour cherry >strawberry >raspberry >quince >apple >melon >apricot. The highest value of antioxidant property was observed in bilberry (61.80%) followed by blackberry (60%) and black mulberry (58.10%) (Yildirim, 2006).

Chowdhury and Ray (2007) reported that red wine from jamun fruit was acidic in taste [titratable acidity (1.11g tartaric acid/100 ml)], with high tannin (1.7mg/100 ml) and low alcohol content (6%).

Wines are considered to be safer to drink than water or milk because of presence of alcohol content in sufficient concentration to kill pathogenic microorganisms (Bisson and Butzkc, 2007).

Effect of enzymatic maceration on synthesis of higher alcohols during mango wine fermentation was studied by Reddy and Reddy (2009). They found that mango wines produced from pectinase treated Banganapalli and Totapuri varieties had highest alcohol content of 8.5% and 7% respectively compared to mango wines produced from without pectinase treated Banganapalli and Totapuri varieties with alcohol content of 6.3% and 5.1% respectively.

Sibounnavong *et al*. (2010) reported that star gooseberry wine produced higher ethyl alcohol (15.90%) than carambola wine (8.28%). The custard apple wine had high scavenging capacity (36.8%) as compared to wines of pineapple (35.6%), lime (20.1%), tamarind (15.7 %), garcinia (15.4%), rambutan (15.1%), and star gooseberry (14.8%) (Nuengchamnong and Ingkaninan, 2010 ; Jagtap and Bapat, 2015). The highest radical-scavenging activity of DPPH was demonstrated by wines prepared from Alphonso (91%), Sindhura (90%) and Banginapalli (88%) cultivars of mango respectively (Varakumar *et al*., 2011).

According to Awe (2011), acidity of wines lies between pH 3 and 7 for dry wine and 3.5 to 4.5 for sweet wine. Titratable acidity, pH and sugar content dropped from 0.2 to 0.4%, 4.4 to 3.1 and 15 to 1% respectively during aerobic fermentation of papaya wine.

According to Vikas *et al*. (2011), the custard apple wine of 1:4 dilution with di ammonium hydrogen phosphate recorded higher alcohol content of 8.14 v/v compared to 1:3 dilution with di ammonium hydrogen phosphate (8.06 v/v) and 1:2 dilution with di ammonium hydrogen phosphate (8.03v/v).

According to Gavimath *et al*. (2012), the TSS content, microbial count, and pH were decreased with increase in alcohol content in banana and papaya wines. Banana wine produced more alcohol content (15.49%) compared to papaya wine (8.73%).

Kumoro *et al*. (2012) reported that jackfruit wine had an alcohol content of 12–13 % within 7 days of fermentation, although Sharma *et al*. (2013) had recommended 14 days to prepare jackfruit wine with 11–13 % alcohol.

Wine prepared from sapota fruit pulp is a peculiar beverage rich in antioxidants with an alcohol concentration of 8.23% (v/v) (Panda *et al*., 2014b). Panda *et al*. (2014a) reported that the alcohol content of wine prepared from bael fruits rich in antioxidants was 7.87%.

Panda *et al*. (2014b) observed that the titratable acidity was increased from must (0.82g tartaric acid / 100 ml) to sapota wine (1.29g tartaric acid/ 100 ml).

Fruit wines contain 8 to 11 percent alcohol and 2 to 3 percent sugar with energy content of between 70 and 90 kcal per 100 mL (Swami *et al*., 2014).

According to Aye *et al*. (2014), the tannin content of star fruit wine was 0.47%, contributing to the texture, taste and colour of the wine. The maximum yield of alcohol (10.98%) was acquired by fermenting 500 gm of star fruit, 1000 mL of distilled water and 200gm of sugar after 4 weeks of fermentation.

Jagtap and Bapat (2015) observed that phenol content of custard apple wine was lower (9.8 mg GAE/100 mL) as compared to red wine that contains high phenolic content (256.7 mg GAE/100 mL). The total phenol content of 0.99 mg g^{-1} was recorded in nutmeg wine (Simenthy, 2015).

According to Vazhacharickal *et al*. (2016), highest content of alcohol in wines was recorded in the order Bilimbi (0.39 ± 0.014) > Java Apple > Ginger > Gooseberry > Coffee > Pepper (0.25 ± 0.009). Highest content of vitamin C (12.73 ± 3.60) was found in gooseberry wine while lowest in ginger wine (1.13 ± 0.12). They also observed that total acidity of gooseberry wine was 8.26 ± 0.015% and bilimbi wine recorded a volatile acidity of 0.39 ± 0.014% after 20 days of fermentation.

The average content of total phenol was highest in cherry, blackcurrant, and blackberry wines (GAE of 3086 mg/L), moderate in raspberry and strawberry wines and the lowest in apple wines (225 mg/L). The wines prepared from cherry (12.04 mmol/L) followed by blackcurrant (11.69 mmol/L), blackberry (11.48mmol/L), and raspberry (9.94 mmol/L) had a notably higher antioxidant capacity than strawberry (5.31 mmol/L) and apple wines (4.04 mmo/L) (Ljevar *et al*., 2016).

Panda *et al*. (2016) reported that jackfruit wine had a titratable acidity of 1.16 (g tartaric acid/100 ml) and alcohol content of 12%. According to them the total sugar content of jackfruit wine was 4.32%. Berkly (2019) reported that the alcohol content of bilimbi wine ranged between 12%-15%.

Cholassery *et al*. (2019) observed that the alcohol content of papaya wine was increased from 3.01% to 10.11% and the pH was decreased from 5.10 to 4.45 during fermentation.

Sebastian *et al*. (2019) reported that the TSS content and titratable acidity of five accessions of sweet lovi-lovi (*Flacourtia* spp.) ranged from 17 to 21.33°Brix and 0.92 to 1.42 per cent respectively.

Kiin Kabari *et al*. (2019) reported that pH of yellow paw-paw must and rose red paw-paw must were decreased from 4.7 to 3.4 and 4.0 to 3.4 respectively on the 14th day of fermentation. They also found that alcohol content of yellow and red pawpaw wines were 8% and 7.69% respectively and the yellow pawpaw wine was preferred over red pawpaw wine because of its high alcohol content and high acidity.

2.5. Factors affecting wine quality

Wine quality is dependent on the substrate, content of sugar, yeast strains, storage conditions and climatic conditions (Esteves and Orgaz, 2001; Jones and Davis, 2000). Different parameters such as skin contact time, temperature, pressing technique use, etc. are controlled by the winemakers to manage the process of fermentation in a proper manner (Bolarin *et al*., 2016).

2.5.1. Fruit: water concentration

According to Vyas and Joshi (1982), plum wine produced with 1:1 dilution was rated to be the best with better acceptable quality. Apricot wine produced with 1:2 dilution was found to be the best wine based on sensory quality (Joshi *et al*., 1990).

According to Vikas *et al*. (2011), custard apple wine prepared by 1:4 dilution was the best wine in terms of color, aroma, flavor, and taste.

The yield of alcohol was maximum (10.98%) reported in starfruit wine prepared using fruit-water ratio of 1:2 after 4 weeks of fermentation (Aye *et al*., 2014).

Sugarcane blended with watermelon juice at 1:1 (v/v) ratio produced wine with good colour, flavour, and overall acceptability and chemical composition of TSS 30.3°Brix and pH of 4.5 during fermentation (Helen *et al*., 2016).

According to Bolarin *et al*. (2016), sensory evaluation of pink rose apple wine prepared from sliced fruit: sugar: water in 1:1:1 ratio recorded highest score for taste.

2.5.2. Fruit: sugar concentration

Kundu *et al*. (1976) reported that banana (*Musa paradisiaca*) fruits can be converted into wine. They found that the alcohol and total phenol content of wine were found to be inversely proportional to the dilution level whereas they are directly proportional to sugar content.

Attri (2009) found that the alcohol content increased with increased initial sugar concentration of the cashew must. The alcohol content of cashew apple wine with an initial sugar concentration of 24 °B was 8.9%. Alcohol content at initial sugar concentrations of 22 °B and 20 °B were 8.25% and 7.81% respectively. But better acceptability was received for cashew apple wine prepared from the initial sugar concentration of 22 °B.

According to Berkly (2019), bilimbi wine prepared from fruit soaked in 50 °Brix solution had the lowest alcohol content (12.56%) with highest level degree brix and wine had the highest alcohol content (14.6%) when prepared from bilimbi fruit soaked in 65° Brix.

A good quality jackfruit wine with 12.13% v/v of ethanol was produced from the fermentation of jackfruit juice of 14 % w/w sugar concentration (Kumoro *et al*., 2012).

When dealing with fruits other than grapes, sugar may need to be added to stimulate the fermentation process in case the fruit does not have enough natural sugar to ferment in the presence of yeast (Saranraj *et al.*, 2017).

Adiyaman *et al*. (2019) reported that the actual flavour of star fruit juice did not change by the addition of sugar during wine processing.

2.5.3. Nitrogen source

Wine produced from 1:4 dilution of guava pulp with addition of 0.1% di ammonium hydrogen phosphate was found to have high ethanol content and best in sensory qualities than the non-supplemented one (Shankar *et al*., 2006).

Custard apple wine of 1: 4 dilution with di ammonium hydrogen phosphate resulted in highest rate of fermentation (1.32 °B/24 hours). The maximum fermentation efficiency was found in 1:3 dilution with DAHP (88.05 %). Irrespective of dilutions, addition of DAHP increased the rate of fermentation (Vikas *et al*., 2011).

Kocher and Pooja (2011) found that supplementation of diammonium hydrogen phosphate (DAHP) improves the guava (*Psidium gujava* L.) wine colour, total acids, bouquet, taste, aroma and overall acceptability. Wines produced from three different varieties of guava had higher ethanol content (13.6%) with a fermentation efficiency of 93.8% by the addition of 0.3% DAHP (Pooja, 2011).

2.5.4. Enzyme treatment

Shukla *et al*. (1991) reported that jamun wine prepared using 0.25% pectic enzyme has good quality after ageing of six months based on sensory evaluation.

Kotecha *et al*. (1994) observed that 0.2% pectinase enzyme treatment to banana must is perfect for wine production.

Reddy and Reddy (2009) found that pectinase treatment increases the alcohol content of mango wine. They also reported that the pectinase treated juice fermentations were completed in 10 days, while untreated ones needed more than 12 days.

Sevda *et al*. (2011) reported that pectinase treated banana produced better quality wine as compared to wine prepared without enzyme treatment.

Egwim *et al*. (2013) examined the effects of pectinase addition on yield and organoleptic evaluation of juice and wine from banana and paw-paw. They found that wine yields of pectinase added banana and paw-paw were 63.4% and 78.7% respectively, while wine yields of banana and paw-paw without the addition of enzyme were 38% and 43%, respectively.

Nikhanj *et al*., (2017) observed that appearance of wine produced from guava must treated with pectinase enzyme was better than those produced from untreated must during storage.

2.6. Sensory qualities of fruit wines

Joshi *et al*. (2005b) prepared strawberry (Fragaria X Ananassa duchensne) wine from three different cultivars. Wine from cultivar Caramosa had higher sensory qualities and acceptability than the other two cultivars (Doughlas and Chandler).

According to Mohanty *et al*. (2006), sensory evaluation score of the cashew apple wine was quite acceptable. But there exists significant differences ($P < 0.01$) between the cashew wine and the commercial grape wine particularly in terms of taste, aroma, flavour and aftertaste because of probably high tannin content in the cashew wine.

The organoleptic evaluation results of jamun wine was accepted as that of wine but jamun wine was significantly different ($P<0.05$) from the commercial grape wine in terms of taste, flavour and after taste mainly due to the high tannin content in the jamun wine. The panelists evaluated the jamun wine as inferior to the commercial grape wine analysing the sensory aspects irrespective of liking the attributes like aroma, taste, after-taste and colour/appearance (Chowdhury and Ray, 2007).

Sensory evaluation of litchi wine showed that a unique “rose” flavour was liked much by the panelists (Kumar *et al*., 2008).

Sevda *et al*. (2011) reported that pectinase enzyme treated ripe banana with two strains of *Saccharomyces cerevisiae* such as NCIM 3283 and NCIM 3046 produced good quality banana wine in terms of flavor, taste, clarity, and overall characteristics.

Sensory evaluation of pawpaw wine showed that the panelists rated 70% acceptability as compared to red wine (Carlo Rossi) (Awe, 2011).

Sensory evaluation rated by the panellists showed that banana wine was acceptable in terms of flavour, taste, clarity and overall characteristics (Sevda *et al*., 2011).

Joshi *et al*. (2012b) showed that jamun wine with 1:1dilution was considered best as table wine due to the good appearance, colour, total acidity, sweetness, body and overall impression.

Sensory evaluation of star fruit wines has shown that *panelists* have rated the best quality, in terms of color, clarity, aroma and taste (Aye *et al*., 2014).

Panda *et al*. (2016) reported that the sensory analysis of jackfruit wine showed a strong, exotic and unique taste and the flavour was “liked much” by the panellists.

According to Musyimi (2016) mango wine possessed a pleasant aroma and mouthfeel and is comparable to grape wine.

Kumar *et al*. (2016) reported that changes in the physico-chemical characteristics of custard apple wine during maturation were reflected in the sensory quality. The improvement in aroma, taste and flavour because of the hydrolysis of the non-reducing sugar which is desirable from the point of view of taste and the composition of the esters is responsible for the fruity flavour in wine.

Colour is one of the most important factors determining quality of wine (Klaric *et al*., 2017).

Akubor (2017) studied the characterization of fruit wines from tropical fruits of baobab (*Adansonia digitata*), pineapple (*Ananas sativus*) and carrot (*Daucus carota*). The study demonstrated that pineapple wine has a higher sensory score than other wines including reference wines for all the attributes except mouthfeel.

The sensory score of taste was found maximum in the starfruit wine prepared using sugar than using jaggery after six months of storage (Adiyaman *et al*., 2019).

Sensory evaluation showed that the yellow pawpaw wine was more preferred than red pawpaw wine due to high score for taste in the former (Kiin Kabari *et al*., 2019).

2.7. Storage stability

The ageing of wine and its potential to improve the quality of wine for consumption is an important step after wine production (Robertson, 2006).

Maturation is a very important and common technical process used in winemaking that makes the wine mellow in taste and fruity in flavour apart from clarification (Kumar *et al*., 2016).

A reduction in the titratable acidity in the wine prepared from more acidic fruits during maturation is desirable as it enhances the palatability of the wine (Joshi *et al*., 1999).

Oxidative and non-oxidative polymerization and precipitation of phenolic compounds take place during maturation that results in smoother and softer taste of wine (Buglione and Lozano, 2002).

According to Sharma and Joshi (2003) TSS content of strawberry wines from the cultivars of Camarosa (9.8 to 9.6°Brix) and Doughlas (9.1 to 8.7°Brix) and titratable acidity also decreased during storage. Sensory analysis of strawberry wines after nine months of storage indicated that the panellists rated higher scores for each attribute except colour than the initial scores.

Perez-Prieto *et al*. (2003) reported that increasing the storage time significantly reduced volatile compounds in red wine.

A study of qualitative changes in banana pulp and juice wines by Shanmugasundaram *et al*. (2005) reported that there was no change in the alcohol content of the banana wine after three months of storage.

The quality of wine is determined by the moisture present in the surrounding areas. Low humidity level could dry the cork and cause deformation. If excessive air is allowed to enter the bottle and comes into contact with the wine it hastens the process of spoilage caused by oxygen (Hyun-Jung *et al*., 2008).

Chira *et al*. (2012) observed that the total tannin content of Cabernet Sauvignon wines was decreased during storage. Rearrangement reactions between phenolic compounds take place during ageing that influence the degree of polymerization in wines. Ageing of wines in bottles was subjected to oxidative reactions if the bottle closures allow oxygen to enter into the wine.

According to Kalyani (2011), overall acceptability of karonda (*Carissa carandas* L.) wine showed an increasing trend during storage due to the production of pleasant aroma, improvement of colour, taste and reduction in acidity and phenols. The TSS content of karonda (*Carissa carandas* L.) wine decreased from 9.25°Brix to 7.83°Brix after four months of storage.

Ulla (2011) observed that the alcohol content of pomegranate wine prepared using arils and 20% sugar syrup raised from 7.28 per cent to 7.41 per cent after storage of 3 months.

According to Joshi *et al*. (2012b), the reducing sugar of jamun wine was increased while total soluble solids and alcohol content were decreased after 12 months of storage.

Gavimath *et al*. (2012) observed that the TSS content after one month of maturation in papaya wine varied between 12 °Brix to 10 °Brix and banana wine varied between 14 °Brix to 8 °Brix.

There exists no ‘ideal’ storage temperature for wine in general due to a careful balance between complexity and maturity during wine production and prevention of qualitative characteristics from taking hold. But the wine will distinctly benefit from a reduced risk of spoilage which takes a longer time to develop when the temperature is low (e.g. < 10°C) (Scrimgeour, 2015). Wines stored at low temperature ages much slower and usually have better flavours and tastes (De LA Persa-Owens and Noble, 1997).

Many high quality red wines are aggressive and difficult to drink when young, but their quality improves with age (Mattivi *et al*., 2015).

According to Chaudhary *et al*. (2015), overall acceptability of jamun wine increased because of the decrease in phenol content after storage of two months.

Kumar *et al*. (2016) observed that maturation of custard apple wine for six months improved the wine quality. TSS content of custard apple wine was reduced to 9.87°B and 9.63°B in three and six months of storage respectively from 10.13 °B. They also reported significant decrease in phenol content. The total phenol content was 226 mg l^{-1} initially which was reduced to 175 mg l^{-1} after six months of storage.

The sensory attributes of sweet lovi-lovi wine from accession 5 showed an increasing trend after three months of storage. Alcohol content and phenol content of sweet lovi-lovi wine were increased after storage of three months. The phenol content of sweet lovi-lovi wine showed an increase from 0.22 mg $100g^{-1}$ to 0.33 mg $100g^{-1}$ during storage (Sebastian *et al*., 2019).

The TSS of starfruit wine using sugar decreased from 16.4°Brix to 14.74°Brix during storage of six months (Adiyaman *et al*., 2019). They also reported decrease in pH content and increase in titratable acidity during storage.

Kiribhaga et al. (2020) reported that banana wine prepared from Poovan variety stored in amber colour glass bottles had the highest overall acceptability and the lowest was in wine from Yangambi variety stored in plan bottles after three months of storage.

Packaging is the main aim for protection and maintenance of the original quality of the food and drinks as much as possible. Primary physicochemical factors that allow the package to achieve its purpose are oxygen, carbon dioxide, moisture, light and aroma-binding properties (Grant-Preece *et al*., 2017).

The maturation in oak barrel is normally reserved for wines designed for medium to long term ageing as oak contributes to the aromatic complexity of wine. Oak barrel can also extend the ageing potential by supplying small quantities of oxygen for red wines, that stabilizes the colour of wines, as well as increasing the concentration of ethyl esters (Salinas *et al*., 1996).

Soni *et al*. (2009) observed that amla wine stored in oak barrels for a whole month improved the quality and sensory characteristics than wine stored in glass bottles. Musyimi, (2016) found that wine stored at low temperatures of 10°C and 15°C in brown bottles manifested low browning indices when compared to wine stored in green and clear bottles.

Glass is the classical packaging material for wine because of the inactivity and clarity. Amber and green coloured dark bottles offer greater protection from light than clear and light coloured bottles (Grant-Preece *et al*., 2017).

Materials and Methods

3. MATERIALS AND METHODS

An experiment on "Technology refinement for wine production from under exploited fruits" was conducted at the Department of Post Harvest Technology, College of Agriculture, Vellayani, Kerala Agricultural University, Thiruvananthapuram in 2019-2021, with the primary objective for improving technology refinement for wine production from under exploited fruits based on quality parameters and storage stability. The materials used and methods adopted for the research program are described in this chapter.

3.1.1. Selection of fruits

The following three underexploited fruits (Plate 1) were used independently to prepare the wine. Ripe, fresh and good quality fruits were collected from Instructional Farm, College of Agriculture, Vellayani or from farmers' fields.

1. Jamun (*Syzygium cumini*)
2. Papaya (*Carica papaya*)
3. Rose apple (*Syzygium jambos*)

3.1.2. Fruit wine preparation

Wines were prepared using baker’s yeast (*Saccharomyces cerevisiae*) by adopting three different methods *viz*., based on accepted household practice, the result of the previous study and based on the specifications prescribed by the FSSAI.

Collected fruits were cleaned by washing, seeds removed, crushed and filled in clean clay pots. Crushed fruits and lukewarm water were mixed independently in three different concentrations.

R_1 – 1:1 w/v (Accepted household practice)

R_2 – 1:2 w/v (Das, 2019)

R_3 – 1:0.07 w/v (FSSAI, 2019)

Initial TSS of the fruit-water mixture was recorded using a hand refractometer and refined sugar was added to the fruit-water mixture as per the treatments. Crushed fruit and sugar were mixed in three different proportions with or without di ammonium hydrogen phosphate (DAHP) as a source of nitrogen.

C_1 – 1:1 w/w (Accepted household practice)

C_2 – For maintaining 24° brix

C_3 – 20% sugar (FSSAI, 2019)

N_1 –with DAHP (0.1%)

N_2 – without DAHP

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 was added to the mixture to supply 50-70 ppm SO_2 to control wild yeast and undesirable bacteria.

The primary fermentation was allowed till the froathing ceased. During primary fermentation the contents were stirred on alternate days to provide the uniform air and to maintain a sufficient temperature. The alcoholic ferment produced after primary fermentation was filtered and subjected to secondary fermentation for another 15 days after adopting two different clarification methods.

Cl_1- Pectinase @ 5g/ml (Das, 2019)

Cl_2 – Clarification by settling (Accepted household practice)

The parameters viz., strain and concentration of yeast, pH of the must and concentration of SO_2 were maintained uniformly.

Fruit: Water ratio (R)	- 3
Fruit: Sugar ratio (C)	- 3
Nitrogen source treatments (N)	- 2
Clarification treatments (Cl)	-2

Total number of treatments - 3×3×2×2 = 36

Jamun Papaya

Rose apple

Plate 1. Fruits selected for wine preparation

Replication - 2

Design - CRD

The resulting fruit wine was filtered after 15 days of secondary fermentation, pasteurized at 85-88°C for two minutes and bottled in amber coloured glass containers (Plate 2.)

The whole experiment was conducted for three fruits separately.

3.2. Quality analysis of fruit wines

The prepared fruit wines were analysed for following physical, chemical and sensory quality parameters.

3.2.1. Physical quality parameters

Physical properties of wine viz., rate of fermentation and fermentation efficiency were analysed.

3.2.1.a. Rate of fermentation (°Brix/24 hours)

The rate of fermentation was expressed in terms of degree brix per 24 hours using following formula (Vikas *et al*., 2011).

$$\text{Rate of fermentation} = \frac{\text{Initial TSS of must} - \text{Final TSS of must}}{24}$$

3.2.1.b. Fermentation efficiency (%)

The fermentation efficiency was expressed as follows (Vikas *et al*., 2011).

$$\text{Fermentation efficiency} = \frac{\text{Actual alcohol}}{\text{Theoretical alcohol}} \times 100$$

Theoretical alcohol = sugar used x 0.64, where as

Sugar used = Initial TSS – Final TSS

3.2.1.c. Yield (%)

Weight of the wine received after the completion of secondary fermentation and expressed in per cent.

3.2.2. Chemical quality parameters

Chemical properties of wine viz., total soluble solids (TSS) (°Brix), titratable acidity (%), sugar content (g100g^{-1}), alcohol content (%), polyphenol content (mgg^{-1}) and antioxidant activity (% inhibition) were analysed.

3.2.2.a. TSS (°Brix)

The Total Soluble Solids (TSS) of wine was determined by using hand refractrometer (0-32°Brix & 30-62°Brix) and expressed in °Brix.

3.2.2.b. Acidity (%)

The titratable acidity of the wine was measured (Ranganna, 1986) and expressed in per cent.

5 mL of wine sample was taken and added 100 mL distilled water, boiled for 30 minutes, the solution was filtered using muslin cloth and made up to 100 mL with distilled water. 25 mL solution was taken, mixed with 25 mL of distilled water and three drops of phenolphathalein indicator was added to it. This was titrated against 0.1N NaOH until the pink colour was attained. The acidity of the wine was expressed in terms of citric acid equivalent using following formula.

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

3.2.2.c. Sugar content ($g100g^{-1}$)

Reducing sugar ($g100g^{-1}$)

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

25 mL of wine sample was taken, and made up to 100 mL with distilled water. Neutralization was done with 1 N NaOH, 2 mL neutral lead acetate was added and kept for 10 minutes after shaking. Excess lead acetate was removed by addition of 2 mL potassium oxalate, the solution was filtered and made up to required volume to produce a clarified solution.

Fehling's solution A and B, 5 mL each were pipetted out, added 50 mL of distilled water and was transferred into a 250 mL conical flask. The burette was filled with the clarified sample and was then added drop by drop to the Fehling's solution. When blue colour of the Fehling's solution changed, three drops of methylene blue indicator was added and the titration was completed till a brick red colour formed. Percentage of reducing sugar was estimated according to the given formula

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

Total sugar ($g100g^{-1}$)

The total sugar content was determined in terms of invert sugar using the following formula (Ranganna, 1986).

25 mL of clarified sample solution prepared for the estimation of reducing sugar was pipetted into 250mL conical flask to which distilled water 50 mL and citric acid (5 g) were added. The solution was boiled for 10 minutes to complete the inversion, cooled, and neutralized with 1N NaOH using phenolphthalein indicator and was made up to required volume. Fehling's solutions A and B, 5 mL each were pipetted and 50 mL distilled water was added and boiled vigorously. The burette was filled with clarified wine sample and added to the boiling Fehling solution drop by

drop until the blue colour faded. When the blue colour of the solution changed, 3 drops of methylene blue indicator were added and the titration was completed till the indicator was completely discoloured and a brick red colour developed.

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

3.2.2.d. Alcohol content (%)

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

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

The flasks were loosely sealed and heated in a water bath at 50°C for 60 minutes. 10 ml of 0.5 M potassium iodide was added to the flask after being removed from the water bath and the contents were titrated with a solution of 0.1 M sodium thiosulphate solution. When brown color of the solution acquired a green tinge, 1ml of 1% of the freshly prepared starch indicator was added, which was prepared in boiling water. The addition of sodium thiosulphate was continued until the solution acquired a clear blue and green color which was considered as the end point of titration. The alcohol content of the wine was calculated using the following formula:

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

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 = $3 \times n_1$

Volume of alcohol in 5 ml of the diluted sample = $3\, n_1 \times 58.6$

Volume of alcohol in 100 ml diluted sample = $[(3\, n_1 \times 58.6) \times 50]$

Percentage of alcohol present in 10 ml of original sample = $[(3\, n_1 \times 58.6) \times 50 \times 10]$

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

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

Wine sample (1 ml) was mixed with 10 times of 80% ethanol and the homogenate was centrifuged at 10,000 rpm for 20 minutes. The supernatant was then dried and the residue was dissolved in 5 ml of distilled water. 0.5 ml of aliquot was pipetted out into the test tubes, made up the volume to 3 ml with distilled water and 0.5 ml reagent of Folin-Ciocalteu was added. Sodium carbonate (Na_2CO_3), 20 percent (2ml) was added to the test tubes after 3 minutes and mixed well. The test tubes were immersed in boiling water for one minute, cooled and the absorbance was measured at 765 nm against the reagent blank.

The standard curve was prepared using various concentrations of gallic acid and the phenol content was expressed as mg phenol g^{-1} of wine.

3.2.2.f. Antioxidant activity (%)

Antioxidant activity of wine was determined using 2, 2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay as per the procedure described by Sharma and Bhat (2009).

Wine sample (1ml) was added to 2 ml 0.1mM DPPH solution, mixed well and left for 30 minutes at room temperature. The absorbance was read at 517 nm and the result was expressed as percentage of DPPH inhibition as per the following equation:

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

Where,

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

A_{sample} – Absorbance of the test sample after 30 minutes.

3.2.3. Sensory quality parameters

Wines prepared by different methods were evaluated by a 30 member semi-trained panel constituted by potential buyers and occasional drinkers selected from College of Agriculture, Vellayani and organoleptic evaluation was carried out using the AWS Wine Evaluation Form (American wine society, 2020).

AWS Wine Evaluation Form

It is a 20 point evaluation scale developed by American wine Society based on modified “Davis system” of evaluation. Davis system was developed at the University of California at Davis in 1959 which assigns a certain number of points to each of ten categories which are then added to obtain the overall rating score for a given wine. AWS has modified the number of categories to five: Appearance (0-3), Aroma & Bouquet (0-6), Taste & Texture (0-6), Aftertaste (0-3), and Overall Impression (0-2). Wines are rated in each category and the total dictates the rating of the wine according to the criteria below.

- 18 - 20 Extraordinary
- 15 - 17 Excellent
- 12 - 14 Good
- 9 - 11 Commercially acceptable

- 6 - 8 Deficient
- 0 - 5 Poor & Objectionable

The sensory analysis score card is used for the study shown as Appendix 1

3.3. Selection of superior fruit wines

Three superior wines prepared from each fruit were selected independently based on high yield, superior antioxidant activity, alcohol content with in the approved range of low alcoholic beverages accepted by Kerala State Government (not more than 7%) and with good sensory quality parameters.

3.4. Storage studies

The three superior wines selected from each fruit were stored for a period of two months in amber coloured glass bottles (Plate 2) under ambient storage condition (30-35°C & 70-83% RH) independently for analysing the storage stability.

Number of wines – 3

Storage period – 2

Total number of treatments – 3×2 = 6

Replication – 5

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. Microbial count

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

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

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

Polyphenol content of the superior wines were assessed as per 3.2.2.e.

3.4.1.c. Alcohol content (%)

Alcohol content of the superior wines was recorded as in 3.2.2.d.

3.5. Statistical Analysis

Data generated in the experiment were statistically analysed using Completely Randomized Design (CRD). The sensory scores of various wines were statistically analysed using the Kruskall-wallis test (square value of chi) and ranked (Shamrez et al., 2013).

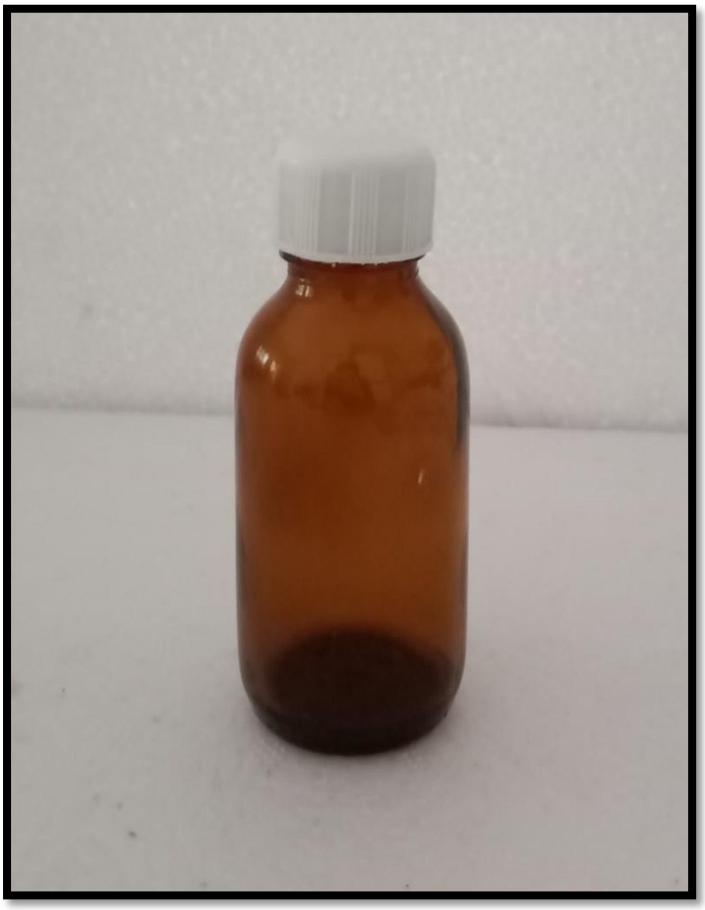


Plate 2.Container selected for storage studies

Results

4. RESULTS

The experiment entitled “Technology refinement for wine production from under exploited 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 superior fruit wines
4. Storage stability of selected fruit wines

4.1. FRUIT WINE PREPARATION

Fruit wines were prepared from three underexploited fruits viz., jamun, papaya and rose apple separately by varying the process parameters *viz*., fruit: water ratio, fruit: sugar ratio, nitrogen source and clarification methods. Fruit: water ratio was tried at 1:1, 1:2 and 1.0.07; fruit: sugar ratio was at 1:1, for maintaining 24° brix and 20% sugar, addition of with or without nitrogen source, thus forming 18 different fruit wines under each fruit. The resultant 18 different fruit wines produced after primary fermentation were analysed for physical quality parameters and subjected to clarification by pectinase enzyme and by settling, thus forming 36 different fruit wines under each fruit.

4.2. QUALITY ANALYSIS OF FRUIT WINES

4.2.1. Jamun

4.2.1.1. Physical quality

The physical quality parameters *viz*., rate of fermentation and fermentation efficiency of 18 jamun wines were recorded after primary fermentation and presented in Tables 1-2.

Rate of fermentation (°Brix/24 hours)

The highest rate of fermentation (0.045°Brix/24 hours) was obtained in wines when fruit: sugar ratio was maintained at 24° brix and the lowest rate (0.033°Brix/24 hours) was recorded when 1:1 fruit: sugar ratio was adopted (Table 1).

There was no significant difference between the rate of fermentation of wines produced with different fruit: water ratio and nitrogen source.

When the interaction effect was studied, the highest rate of fermentation (0.056°Brix/24 hours) was obtained for the jamun wine prepared with 1:2 fruit: water ratio, maintaining 24° brix and with nitrogen source. This was on par with wine produced in same manner but without nitrogen source (0.054°Brix/24 hours). Wines prepared using 1:1 fruit: water ratio, maintaining 24° brix and with or without nitrogen source (0.051°Brix/24 hours) and wines with 1:0.07 fruit: water ratio, 20% sugar and with (0.052°Brix/24 hours) or without (0.055°Brix/24 hours) nitrogen source were also on par. The lowest rate of fermentation (0.013°Brix/24 hours) was obtained for wine produced with 1:0.07 fruit: water ratio, 1:1 fruit: sugar ratio and without nitrogen source.

Fermentation efficiency (%)

Highest fermentation efficiency (180.81%) was recorded when fruit: water ratio was 1:0.07 and lowest rate (117.77%) was recorded when 1:1 fruit: water ratio was adopted (Table 2).

The highest fermentation efficiency (215.77%) was recorded when fruit: sugar ratio was maintained at 20% sugar and lowest (70.17%) was obtained in wine produced with 1:1 fruit: sugar ratio

There was no significant difference between the fermentation efficiency of wines produced with and without nitrogen source.

Table 1. Effect of process parameters on rate of fermentation of jamun wines

Rate of fermentation (°Brix/24 hours)						
Fruit water ratio (R)	With nitrogen source (N_1)			Without nitrogen source (N_2)		
	Fruit: sugar 1:1 (C_1)	Fruit: sugar to maintain 24°Brix (C_2)	20% sugar (C_3)	Fruit: sugar 1:1 (C_1)	Fruit: sugar to maintain 24°Brix (C_2)	20% sugar (C_3)
R_1 (1:1)	0.029	0.051	0.042	0.04	0.051	0.044
R_2 (1:2)	0.048	0.056	0.028	0.044	0.054	0.028
R_3 (1:0.07)	0.022	0.028	0.052	0.013	0.028	0.055
Mean R	R_1 = 0.042		R_2 = 0.043		R_3 = 0.033	
Mean C	C_1 = 0.033		C_2 = 0.045		C_3 = 0.041	
Mean N	N_1 = 0.039		N_2 = 0.039			
CD (0.05)	R= NS	C= 0.005		N=NS	R×C×N= 0.006	

Table 2. Effect of process parameters on fermentation efficiency of jamun wines

Fermentation efficiency (%)						
Fruit water ratio (R)	With nitrogen source (N_1)			Without nitrogen source (N_2)		
	Fruit: sugar 1:1 (C_1)	Fruit: sugar to maintain 24°Brix (C_2)	20% sugar (C_3)	Fruit: sugar 1:1 (C_1)	Fruit: sugar to maintain 24°Brix (C_2)	20% sugar (C_3)
R_1 (1:1)	75.52	102.00	173.95	46.80	116.37	191.95
R_2 (1:2)	65.25	139.06	245.72	58.90	141.6	244.91
R_3 (1:0.07)	85.79	240.3	227.59	89.14	231.55	210.50
Mean R	R_1 = 117.77		R_2 = 149.17		R_3 = 180.81	
Mean C	C_1 = 70.17		C_2 = 161.81		C_3 = 215.77	
Mean N	N_1 = 150.57			N_2 = 147.97		
CD (0.05)	R= 6.24	C= 11.36		N= NS	R×C×N= 32.79	

When the interaction effect was considered, the highest fermentation efficiency (245.72%) was recorded in the jamun wine produced using 1:2 fruit: water ratio, 20% sugar and with nitrogen source. This was on par with the wine produced in same manner but without nitrogen source (244.91%). The wines produced using 1:0.07 fruit: water ratio, maintaining 24° brix and with (240.3%) or without (231.55%) nitrogen source and wines with 1:0.07 fruit: water ratio, 20% sugar and with nitrogen source (227.59%) were also on par. The lowest fermentation efficiency (46.80%) was recorded in wine prepared with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio and without nitrogen source. This was on par with wine produced in same manner but with nitrogen source (75.52%). Wines prepared with 1:2 fruit: water ratio, 1:1 fruit: sugar ratio and with (65.25%) or without (58.90%) nitrogen source were also on par.

Yield (%)

The highest yield (89.25%) was recorded when fruit: water ratio was 1:2 and the lowest content (79.34%) was recorded when 1:0.07 fruit: water ratio was adopted (Table 3).

Highest yield (86.26%) was observed in wines produced when fruit: sugar ratio was maintained at 24° brix and the lowest (81.47%) was recorded when 20% sugar was adopted.

Higher yield (85.5%) was recorded for wines prepared with nitrogen source and the lower (84.83%) was recorded in wines produced without nitrogen source.

There was no significant difference between the yield of wines prepared with clarification methods.

When the interaction effect was considered, the highest yield (95.4%) was noticed in jamun wine produced using 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase. The lowest yield (71.8%) was recorded in the wine prepared with 1:0.07 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase.

Table 3. Effect of process parameters on yield of jamun wines

Yield (%)												
Fruit water ratio (R)	With nitrogen source (N_1)						Without nitrogen source (N_2)					
	Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°Brix (C_2)		20% sugar (C_3)		Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°Brix (C_2)		20% sugar (C_3)	
	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2
R_1 (1:1)	95.4	91.9	85.1	82.7	*	*	92.9	89.2	85.7	83.3	*	*
R_2 (1:2)	92.8	85.9	88.4	88.4	*	*	85.7	89.6	92.3	90.9	*	*
R_3 (1:0.07)	71.8	76.7	*	*	81.2	85.7	74.8	78.5	82.9	82.9	77.3	81.7
Mean R	R_1= 88.27				R_2= 89.25				R_3= 79.34			
Mean C	C_1= 85.43				C_2= 86.26				C_3= 81.47			
Mean N	N_1= 85.5						N_2= 84.83					
Mean Cl	Cl_1= 85.1						Cl_2= 85.2					
CD (0.05)	R=0.57		C=0.24		N= 0.29			Cl= NS		R×C×N×Cl= 0.70		

*- Contaminated; Cl_1 – Clarification using pectinase; Cl_2 – Clarification by settling

The following five wines were contaminated after primary fermentation.

1. Wines prepared with 1:1 fruit: water ratio, 20% sugar and with nitrogen source.
2. Wines prepared with 1:1 fruit: water ratio, 20% sugar and without nitrogen source.
3. Wines prepared with 1:2 fruit: water ratio, 20% sugar and with nitrogen source.
4. Wines prepared with 1:2 fruit: water ratio, 20% sugar and without nitrogen source.
5. Wines prepared with 1:0.07 fruit: water ratio, maintaining 24° brix and with nitrogen source.

4.2.1.2. Chemical quality

The chemical quality parameters of the prepared jamun wines were recorded after secondary fermentation and presented in the Tables 4-10.

TSS (°Brix)

There was significant difference between the TSS content of different jamun wines (Table 4).

The highest TSS content (24.66° brix) was recorded when fruit: water ratio was 1:0.07 and the lowest content (9.96° brix) was recorded when 1:2 fruit: water ratio was adopted.

Highest TSS content (30.12° brix) was observed in wines produced when fruit: sugar ratio was maintained at 1:1 and the lowest (6.35° brix) was recorded when 20% sugar was adopted.

Higher TSS content (18.63° brix) was recorded for wines prepared with nitrogen source and the lower (16.38° brix) was recorded in wines produced without nitrogen source.

Higher TSS content (17.91° brix) was recorded when wines were clarified by pectinase and the lower (16.92° brix) was observed in wines clarified by settling.

When the interaction effect was considered, the highest TSS content (52.4° brix) was noticed in jamun wine produced using 1:0.07 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by pectinase. This was on par with wine produced in same manner but clarified by settling (52.1° brix). The lowest TSS content (4.6° brix) was recorded in the wine prepared with 1:1 fruit: water ratio, maintaining 24° brix, without nitrogen source and clarified by settling. This was on par with wine produced in the same manner, but clarified using pectinase (5° brix).

Acidity (%)

Acidity content (titratable acidity as citric acid) of different jamun wines were significantly influenced only by interaction effect of fruit: water ratio, fruit: sugar ratio, nitrogen source and clarification methods (Table 5).

When the interaction effect was studied, the highest acidity content (1.1%) was recorded in the wine produced using fruit: water ratio of 1:0.07, 20% sugar, without nitrogen source and clarified using pectinase. This was on par with the wines produced using 1:0.07 fruit: water ratio, 20% sugar, with nitrogen source and clarified by settling (1%), wines with 1:1 fruit: water ratio, maintaining 24° brix, with nitrogen source and clarified by pectinase (0.9%), wines with 1:0.07 fruit: water ratio, without nitrogen source, irrespective of fruit: sugar ratio and clarified by settling and the wine prepared with 1:0.07 fruit: water ratio, maintaining 24° brix, without nitrogen source and clarified by pectinase. The lowest acidity content (0.6%) was recorded in the wines produced with fruit: water ratio of 1:2, fruit: sugar ratio of 1:1, with or without nitrogen source and clarified by settling. Wines produced with 1:2 fruit: water ratio, maintaining 24° brix and without nitrogen source irrespective of clarification method also had the lowest (0.6%) acidity. This was on par with all the other wines except those recorded with the highest acidity content.

Table 4. Effect of process parameters on TSS of jamun wines

TSS (°Brix)												
Fruit water ratio (R)	With nitrogen source (N_1)						Without nitrogen source (N_2)					
	Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°Brix (C_2)		20% sugar (C_3)		Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°Brix (C_2)		20% sugar (C_3)	
	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2
R_1 (1:1)	27.8	27.9	9	5.4	*	*	23.9	23	5	4.6	*	*
R_2 (1:2)	13.6	13.8	7	5.5	*	*	13.4	13	7.2	6.2	*	*
R_3 (1:0.07)	49.6	51	*	*	7	6	52.4	52.1	10.1	6	6.9	5.5
Mean R	R_1=15.82				R_2= 9.96				R_3= 24.66			
Mean C	C_1= 30.12				C_2= 6.6				C_3= 6.35			
Mean N	N_1= 18.63						N_2= 16.38					
Mean Cl	Cl_1= 17.91						Cl_2= 16.92					
CD (0.05)	R= 0.3		C= 0.13		N= 0.18			Cl= 0.71		R×C×N×Cl= 0.49		

*- Contaminated; Cl_1 – Clarification using pectinase; Cl_2 – Clarification by settling

Table 5. Effect of process parameters on acidity of jamun wines

Acidity (%)												
Fruit water ratio (R)	With nitrogen source (N_1)						Without nitrogen source (N_2)					
	Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°Brix (C_2)		20% sugar (C_3)		Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°Brix (C_2)		20% sugar (C_3)	
	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2
R_1 (1:1)	0.7	0.7	0.9	0.8	*	*	0.8	0.7	0.7	0.7	*	*
R_2 (1:2)	0.7	0.6	0.7	0.7	*	*	0.7	0.6	0.6	0.6	*	*
R_3 (1:0.07)	0.8	0.8	*	*	0.7	1.0	0.8	0.9	1.0	0.9	1.1	1.0
Mean R	R_1= 0.75				R_2= 0.65				R_3= 0.9			
Mean C	C_1= 0.73				C_2= 0.76				C_3= 0.95			
Mean N	N_1= 0.76						N_2= 0.79					
Mean Cl	Cl_1= 0.78						Cl_2= 0.77					
CD (0.05)	R= NS		C= NS		N= NS			Cl= NS		R×C×N×Cl= 0.28		

*- contaminated; Cl_1 – Clarification using pectinase; Cl_2 – Clarification by settling

Sugar content (g 100g^{-1})

Reducing sugar (g 100g^{-1})

The highest reducing sugar was recorded (6.40g 100g^{-1}) when fruit: water ratio was 1:0.07 and the lowest (2.26 g 100g^{-1}) was recorded when 1:2 fruit: water ratio was adopted. Highest reducing sugar (8.46 g 100g^{-1}) was recorded in wine when fruit: sugar ratio was maintained at 1:1 and the lowest (0.86 g 100g^{-1}) was recorded in wine produced with 20% sugar (Table 6).

The higher reducing sugar (4.97 g 100g^{-1}) was recorded in wine produced with nitrogen source and the lower (3.98 g 100g^{-1}) reducing sugar was obtained without addition of nitrogen source. Higher reducing sugar (4.63 g 100g^{-1}) was observed when wine was clarified using pectinase and the lower (4.25 g 100g^{-1}) content was recorded when clarified by settling.

When the interaction effect was considered, the highest reducing sugar (14.95 g 100g^{-1}) was recorded in the jamun wine produced with 1:0.07 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by settling. This was on par with the wines produced with same fruit: water and fruit: sugar ratio, but without nitrogen source and clarified by pectinase (14.7 g 100g^{-1}) or by settling (14.45 g 100g^{-1}). The lowest reducing sugar (0.59 g 100g^{-1}) was observed in wine produced with 1:1 fruit: water ratio, maintaining 24° brix, without nitrogen source and clarified by pectinase. This was on par with the wine which was produced in the same manner, but clarified by settling (0.62 g 100g^{-1}) and the wines produced with same fruit: water and fruit: sugar ratio, but with nitrogen source and clarified by both pectinase (1.01 g 100g^{-1}) and settling (0.69 g 100g^{-1}). Wines produced with 1:0.07 fruit: water ratio, 20% sugar, with and without nitrogen source irrespective of clarification method and the wine produced with 1:2 fruit: water ratio, maintaining 24° brix, without nitrogen source and clarification done by settling and wine prepared with 1:0.07 fruit: water ratio, maintaining 24° brix, without nitrogen source and clarified by settling were also on par.

Table 6. Effect of process parameters on reducing sugar of jamun wines

Reducing sugar ($g100g^{-1}$)												
Fruit water ratio (R)	With nitrogen source (N_1)						Without nitrogen source (N_2)					
	Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°Brix (C_2)		20% sugar (C_3)		Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°Brix (C_2)		20% sugar (C_3)	
	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2
R_1 (1:1)	10	8.07	1.01	0.69	*	*	6.24	6.1	0.59	0.62	*	*
R_2 (1:2)	4.04	2.85	1.33	1.27	*	*	3.49	2.76	1.2	1.16	*	*
R_3 (1:0.07)	13.85	14.95	*	*	0.91	0.72	14.7	14.45	1.81	0.82	1.01	0.79
Mean R	R_1= 4.16				R_2= 2.26				R_3= 6.40			
Mean C	C_1= 8.46				C_2= 1.05				C_3= 0.86			
Mean N	N_1= 4.97						N_2= 3.98					
Mean Cl	Cl_1= 4.63						Cl_2= 4.25					
CD (0.05)	R= 0.23		C= 0.18			N= 0.48		Cl= 0.28			R×C×N×Cl= 0.58	

*- contaminated; Cl_1 – Clarification using pectinase; Cl_2 – Clarification by settling

Total sugar (g 100g^{-1})

There was significant difference between the total sugar content of different jamun wines prepared using different process variables (Table 7).

The total sugar content was maximum (20.59 g 100g^{-1}) when wine was produced with 1:0.07 fruit: water ratio and the least (7.12 g 100g^{-1}) was recorded when 1:2 fruit: water ratio was adopted.

Highest total sugar (24.11 g 100g^{-1}) was recorded when fruit: sugar ratio was maintained at 1:1 and the lowest (4.20 g 100g^{-1}) was recorded when sugar was maintained at 24° brix.

The higher total sugar (14.31 g 100g^{-1}) was recorded in wine produced with nitrogen source and the lower (12.79 g 100g^{-1}) total sugar was obtained without addition of nitrogen source.

Higher total sugar (14.18 g 100g^{-1}) was observed when wine was clarified using pectinase and the lower (12.81 g 100g^{-1}) content was recorded when clarified by settling.

When the interaction effect was studied, the highest total sugar (46.50g 100g^{-1}) was observed in the wine prepared with 1:0.07 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified using pectinase. The lowest total sugar (3.05 g 100g^{-1}) was observed in wine produced with 1:1 fruit: water ratio, maintaining 24° brix, without nitrogen source and clarified using pectinase. This was on par with the wine which was produced in same manner, but clarified by settling (3.21 g 100g^{-1}) and the wine prepared with 1:1 fruit: water ratio, maintaining 24° brix, with nitrogen source and clarification done by settling (3.33 g 100g^{-1}).

Alcohol content (%)

Alcohol content of wines was significantly influenced by fruit: water ratio, fruit: sugar ratio and their interaction with nitrogen source and clarification methods, whereas nitrogen source and clarification methods did not significantly influence the alcohol content of wines (Table 8).

Table 7. Effect of process parameters on total sugar of jamun wines

Total sugar (g100g^{-1})												
Fruit water ratio (R)	With nitrogen source (N_1)						Without nitrogen source (N_2)					
	Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°Brix (C_2)		20% sugar (C_3)		Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°Brix (C_2)		20% sugar (C_3)	
	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2
R_1 (1:1)	20.90	19.08	3.93	3.33	*	*	17.5	17.0	3.05	3.21	*	*
R_2 (1:2)	10.12	8.3	4.81	4.36	*	*	12.85	7.61	4.47	4.41	*	*
R_3 (1:0.07)	43.08	43.85	*	*	5.70	4.32	46.50	42.55	5.99	4.43	5.39	4.05
Mean R	R_1=11				R_2=7.12				R_3=20.59			
Mean C	C_1=24.11				C_2=4.20				C_3=4.86			
Mean N	N_1=14.31						N_2=12.79					
Mean Cl	Cl_1=14.18						Cl_2=12.81					
CD (0.05)	R= 0.11		C= 0.10			N= 0.12		Cl= 0.33			R×C×N×Cl= 0.52	

*- contaminated; Cl_1 – Clarification using pectinase; Cl_2 – Clarification by settling

The alcohol content was maximum (9.97%) when fruit: water ratio was 1:2 and the minimum (8.31%) was recorded when 1:1 fruit: water ratio was adopted.

Alcohol content (14.33%) was maximum in wines produced when sugar was maintained at 24° brix and the minimum (4.72%) was recorded when 1:1 fruit: sugar ratio was adopted.

The alcohol content was maximum (15.82%) in jamun wine produced using 1:2 fruit: water ratio, maintaining 24° brix, without nitrogen source and clarified by pectinase. This was on par with the wine produced in same manner but addition of nitrogen source. The wine prepared with 1:1 fruit: water ratio, maintaining 24° brix, without nitrogen source and clarified by pectinase was also on par. The lowest alcohol content (3.52%) was recorded in the wines prepared with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio and clarified using pectinase irrespective of nitrogen source and wines with 1:0.07 fruit: water ratio, 1:1 fruit: sugar ratio and clarified by settling irrespective of nitrogen source. This was on par with wines produced with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, clarified by settling and with (5.86%) or without (4.39%) nitrogen source. Wines prepared using 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase (5.86%) or by settling (6.59%), wines with 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by pectinase (4.32%) or by settling (5.86%) and wines with 1:0.07 fruit: water ratio, 1:1 fruit: sugar ratio, clarified by pectinase and with (4.39%) or without (5.27%) nitrogen source were also on par.

Polyphenol content (mg g^{-1})

The polyphenol content of wines was significantly influenced by fruit: water ratio, fruit: sugar ratio, nitrogen source and their interaction (Table 9).

The lowest polyphenol content (139.49mg g^{-1}) was observed when 1:0.07 fruit: water ratio was used and the highest (212.99mg g^{-1}) content was observed in wines produced with 1:1 fruit: water ratio.

Table 8. Effect of process parameters on alcohol content of jamun wines

Alcohol content (%)												
Fruit water ratio (R)	With nitrogen source (N_1)						Without nitrogen source (N_2)					
	Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°Brix (C_2)		20% sugar (C_3)		Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°Brix (C_2)		20% sugar (C_3)	
	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2
R_1 (1:1)	3.52	5.86	10.55	12.30	*	*	3.52	4.39	14.06	12.31	*	*
R_2 (1:2)	5.86	6.59	14.94	13.18	*	*	4.32	5.86	15.82	13.18	*	*
R_3 (1:0.07)	4.39	3.52	*	*	13.36	12.30	5.27	3.52	12.18	11.06	9.36	10.55
Mean R	R_1=8.31				R_2=9.97				R_3=8.55			
Mean C	C_1=4.72				C_2=14.33				C_3=11.39			
Mean N	N_1=8.86						N_2=8.96					
Mean Cl	Cl_1=9.01						Cl_2=8.82					
CD (0.05)	R= 1.82		C= 2.94			N= NS			Cl= NS		R×C×N×Cl= 1.89	

*- contaminated; Cl_1 – Clarification using pectinase; Cl_2 – Clarification by settling

Lowest polyphenol content (142.08mgg^{-1}) was recorded when fruit: sugar ratio was maintained at 20% sugar and highest (177.21mgg^{-1}) was recorded when fruit: sugar ratio was maintained at 24° brix.

The lower polyphenol content (160.08mgg^{-1}) was recorded in wines without nitrogen source compared to wines produced with nitrogen source (165.11mgg^{-1}).

There was no significant difference between the polyphenol content of wines produced using different clarification methods.

When the interaction effect was considered, the lowest polyphenol content (95.93mgg^{-1}) was recorded when wine was prepared with 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by settling. Highest polyphenol content (253.29mgg^{-1}) was recorded in the wine prepared with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by pectinase.

Antioxidant activity (%)

There was significant difference between the antioxidant activity of different jamun wines (Table 10).

The antioxidant activity was maximum (87.56%) in wines produced with 1:2 fruit: water ratio and minimum (81.51%) was recorded when 1:0.07 fruit: water ratio was adopted.

Highest antioxidant activity (86.66%) was recorded when fruit: sugar ratio was maintained at 1:1 and the lowest (77.33%) was recorded when 20% sugar was used. Antioxidant activity was higher (86.91%) in wines prepared with nitrogen source compared to wines produced without nitrogen source (82.73%).

Higher antioxidant activity (90.21%) was recorded in wines clarified using pectinase compared to wines clarified by settling (79.12%).

When the interaction effect was studied, the highest antioxidant activity (95.64%) was recorded in the wine produced with 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified using pectinase. The wine which was

Table 9. Effect of process parameters on polyphenol content of jamun wines

	Polyphenol content (mgg^{-1})											
Fruit water ratio (R)	With nitrogen source (N_1)						Without nitrogen source (N_2)					
	Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°Brix (C_2)		20% sugar (C_3)		Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°Brix (C_2)		20% sugar (C_3)	
	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2
R_1 (1:1)	188.28	179.19	228.01	223.74	*	*	253.29	182.19	201.01	248.2	*	*
R_2 (1:2)	125.92	187.28	154.1	110.83	*	*	107.28	95.93	150.74	191.56	*	*
R_3 (1:0.07)	151.01	141.38	*	*	134.92	156.65	121.47	148.74	156.92	107.01	149.56	127.2
Mean R	R_1=212.99				R_2=140.45				R_3=139.49			
Mean C	C_1=156.83				C_2=177.21				C_3=142.08			
Mean N	N_1=165.11						N_2=160.08					
Mean Cl	Cl_1=163.27						Cl_2=161.53					
CD (0.05)	R= 2.42		C= 2.38			N= 2.59			Cl= NS		R×C×N×Cl= 4.13	

*- contaminated; Cl_1 – Clarification using pectinase; Cl_2 – Clarification by settling

Table 10. Effect of process parameters on antioxidant activity of jamun wines

Antioxidant activity (% inhibition)												
Fruit water ratio (R)	With nitrogen source (N_1)						Without nitrogen source (N_2)					
	Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°Brix (C_2)		20% sugar (C_3)		Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°Brix (C_2)		20% sugar (C_3)	
	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2
R_1 (1:1)	92.5	89.7	92.83	84.64	*	*	93.03	65.69	86.45	80.92	*	*
R_2 (1:2)	95.64	78.86	94.12	83.36	*	*	93.36	86.23	88.26	80.62	*	*
R_3 (1:0.07)	92.76	89.64	*	*	92.73	56.2	92.66	69.91	76.68	84.09	81.68	78.71
Mean R	R_1=85.72				R_2=87.56				R_3=81.51			
Mean C	C_1=86.66				C_2=85.2				C_3=77.33			
Mean N	N_1=86.91						N_2=82.73					
Mean Cl	Cl_1=90.21						Cl_2=79.12					
CD (0.05)	R= 0.08		C= 0.07			N= 0.11		Cl= 0.07			R×C×N×Cl= 0.15	

*- contaminated; Cl_1 – Clarification using pectinase; Cl_2 – Clarification by settling

produced using 1:0.07 fruit: water ratio, 20% sugar, with nitrogen source and clarified by settling had the lowest antioxidant activity (56.2%).

4.2.1.3. Sensory quality

Sensory quality parameters of jamun wines were recorded after completion of secondary fermentation. There was significant difference in the sensory quality parameters of jamun wines (Table 11).

Appearance

Mean score for appearance of different wines ranged between 1.5 to 3.0. The highest mean score for appearance (3.0) was recorded in the jamun wine prepared with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase. The same score was also obtained for the wine prepared with 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified using pectinase. This was closely followed by the wine prepared with fruit: water ratio of 1:1, fruit: sugar ratio of 1:1, without nitrogen source and clarified by pectinase (2.9). The lowest mean score (1.5) was obtained for the wine prepared with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by settling.

Aroma

Mean score for aroma varied between 3.7 to 5.6. The wine prepared with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified using pectinase had the highest mean score for aroma (5.6) which was closely followed by the wine prepared using 1:1 fruit: water ratio, 1:1 fruit sugar ratio, with nitrogen source and clarified using pectinase (5.5). Wine prepared with 1:0.07 fruit: water ratio, 20% sugar, without nitrogen source and clarified by pectinase had the lowest mean score for aroma (3.7).

Taste/Texture

Mean score for taste/texture of different wines ranged from 2.9 to 5.4. The highest mean score for taste/texture (5.4) was recorded in the wine produced using 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by pectinase. This was closely followed by the wine produced using 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase (5.3). The lowest mean score for taste/texture (2.9) was obtained for the wines with 1:1 fruit: water ratio, maintaining 24° brix, with or without nitrogen source and clarified by pectinase. Wines produced with 1:0.07 fruit: water ratio, maintaining 24° brix, without nitrogen source and clarified by pectinase; 1:0.07 fruit: water ratio, 20% sugar, with nitrogen source and clarified by pectinase; 1:0.07 fruit: water ratio, 20% sugar and without nitrogen source irrespective of clarification method also had mean score of 2.9.

After taste

The mean score for after taste of wines varied from 1.2 to 2.7. The wine produced using 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase had the highest mean score for after taste (2.7). Wines which were produced with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified using pectinase and wines with 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified using pectinase also obtained mean score of 2.7. The wine prepared with 1:1 fruit: water ratio, maintaining 24° brix, with nitrogen source and clarified using pectinase had the lowest mean score (1.2). The same score was obtained for the wines produced with 1:0.07 fruit: water ratio, maintaining 24° brix or 20% sugar, without nitrogen source and clarified using pectinase.

Overall impression

Mean score for overall impression of jamun wines varied between 0.9 to 2.0. The highest mean score for overall impression (2.0) was obtained for the wine prepared with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by pectinase. This was followed by the wines prepared using same fruit: water and fruit: sugar ratio, irrespective of nitrogen source and clarification method (1.8). The lowest mean score for overall impression (0.9) was obtained for the wine prepared using 1:1 fruit: water ratio, maintaining 24° brix, without nitrogen source and clarified using pectinase. Wines prepared with 1:0.07 fruit: water ratio and

Table 11. Effect of process parameters on sensory quality of jamun wines

Treatments	Appearance		Aroma		Taste/Texture		After taste		Overall impression	
	Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank
T_1–1:1 F-W+1:1 F-S+N_1+Cl_1	3.0	207.50	5.5	202.50	5.1	194.60	2.7	203.65	1.8	192.00
T_2–1:1 F-W+1:1 F-S+N_1+Cl_2	1.9	84.30	5.4	194.10	4.8	179.50	2.5	186.45	1.7	179.25
T_3–1:1 F-W+1:1 F-S+N_2+Cl_1	2.9	195.95	5.6	210.90	5.4	211.80	2.7	203.65	2.0	217.50
T_4–1:1 F-W+1:1 F-S+N_2+Cl_2	1.5	53.50	5.4	196.60	4.8	182.60	2.4	179.80	1.8	192.00
T_5–1:1 F-W+24°Brix+N_1+Cl_1	2.1	107.40	3.9	86.50	2.9	76.60	1.2	74.00	1.0	90.00
T_6–1:1 F-W+24°Brix+N_1+Cl_2	2.0	111.25	3.8	96.60	3.1	86.80	1.3	90.15	1.0	94.20
T_7–1:1 F-W+24°Brix+N_2+Cl_1	2.5	149.75	4.0	94.10	2.9	76.00	1.3	86.05	0.9	81.45
T_8–1:1 F-W+24°Brix+N_2+Cl_2	2.1	111.25	3.8	79.80	3.3	97.70	1.5	100.45	1.0	90.00
T_9–1:2 F-W+1:1 F-S+N_1+Cl_1	3.0	207.50	5.1	176.40	5.3	206.10	2.7	203.65	1.7	179.25
T_{10}–1:2 F-W+1:1 F-S+N_1+Cl_2	1.8	80.45	3.8	89.40	4.4	159.70	2.0	145.40	1.4	141.00
T_{11}–1:2 F-W+1:1 F-S+N_2+Cl_1	2.2	115.10	4.6	142.30	5.2	204.10	2.5	188.90	1.7	178.65
T_{12}–1:2 F-W+1:1 F-S+N_2+Cl_2	1.9	88.15	4.8	151.20	5.1	196.70	2.5	187.75	1.7	179.25
T_{13}–1:2 F-W+24°Brix+N_1+Cl_1	2.8	184.40	4.6	141.10	3.7	119.40	1.7	118.95	1.3	128.25
T_{14}–1:2 F-W+24°Brix+N_1+Cl_2	2.0	95.85	4.2	110.00	3.6	114.90	1.6	111.00	1.2	119.70
T_{15}–1:2 F-W+24°Brix+N_2+Cl_1	2.8	184.40	4.9	161.30	3.5	108.20	1.6	108.40	1.2	119.70
T_{16}–1:2 F-W+24°Brix+N_2+Cl_2	2.1	107.40	3.9	94.40	3.4	103.40	1.5	101.75	1.0	94.20
T_{17}–1:0.07 F-W+1:1 F-S+N_1+Cl_1	2.7	176.70	5.1	173.10	4.3	154.15	2.2	160.00	1.5	153.75
T_{18}–1:0.07 F-W+1:1 F-S+N_1+Cl_2	2.3	130.50	4.7	147.00	4.0	137.95	2.0	144.10	1.4	141.00
T_{19}–1:0.07 F-W+1:1 F-S+N_2+Cl_1	2.6	165.15	4.8	153.70	4.1	143.65	2.1	152.05	1.5	153.75
T_{20}–1:0.07 F-W+1:1 F-S+N_2+Cl_2	2.0	99.70	4.5	131.90	4.2	149.45	1.9	136.15	1.4	141.00
T_{21}–1:0.07 F-W+24°Brix+N_2+Cl_1	2.1	107.40	3.9	86.50	2.9	76.60	1.2	74.00	1.0	90.00
T_{22}–1:0.07 F-W+24°Brix+N_2+Cl_2	2.1	111.25	3.8	96.60	3.1	86.80	1.3	90.15	1.0	94.20
T_{23}–1:0.07 F-W+20% Sugar+N_1+Cl_1	2.5	149.75	4.0	120.44	2.9	76.00	1.3	86.05	0.9	81.45
T_{24}–1:0.07 F-W+20% Sugar+N_1+Cl_2	2.1	111.25	3.8	79.80	3.3	97.70	1.5	100.45	1.0	90.00
T_{25}–1:0.07 F-W+20% Sugar+N_2+Cl_1	2.1	107.40	3.7	77.60	2.9	76.60	1.2	74.00	1.0	90.00
T_{26}–1:0.07 F-W+20% Sugar+N_2+Cl_2	2.5	149.75	3.8	85.20	2.9	76.00	1.3	86.05	0.9	81.45
K value	95.36		91.29		107.85		103.57		112.41	
χ^2	37.652									

F-W – Fruit: water ratio; F-S – Fruit: sugar ratio; N_1 – With nitrogen source; N_2 – Without nitrogen source; Cl_1 – Clarified by pectinase; Cl_2 – Clarified by settling

20% sugar, irrespective of nitrogen source and clarification methods also had mean score of 0.9.

4.2.2 Papaya

4.2.2.1. Physical quality

The physical quality parameters viz., rate of fermentation and fermentation efficiency of 18 different papaya wines were recorded immediately after primary fermentation and presented in Tables 12-13.

Rate of fermentation (°Brix/24 hours)

The highest rate of fermentation (0.035°Brix/24 hours) was recorded when fruit: water ratio was 1:2 and the lowest rate (0.025°Brix/24 hours) was recorded when 1:1 fruit: water ratio was adopted (Table 12).

Highest rate of fermentation (0.036°Brix/24 hours) was recorded when fruit: sugar ratio was maintained at 24° brix and the lowest rate (0.022°Brix/24 hours) was recorded in 1:1 fruit: sugar ratio.

There was no significant difference between the rate of fermentation of wines prepared with and without nitrogen source.

When the interaction effect was considered, the highest rate of fermentation (0.051°Brix/24 hours) was recorded in the papaya wine produced using 1:2 fruit: water ratio, maintaining 24° brix and without nitrogen source. The lowest rate of fermentation (0.012°Brix/24 hours) was recorded in wine produced with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio and without nitrogen source. This was on par with wine produced in same manner but with nitrogen source (0.013°Brix/24 hours). Wine prepared with 1:0.07 fruit: water ratio, 1:1 fruit: sugar ratio and with nitrogen source was also on par (0.016°Brix/24 hours).

Table 12. Effect of process parameters on rate of fermentation of papaya wines

Rate of fermentation (°B/24 hours)						
Fruit water ratio (R)	With nitrogen source (N_1)			Without nitrogen source (N_2)		
	Fruit: sugar 1:1 (C_1)	Fruit: sugar to maintain 24°B (C_2)	20% sugar (C_3)	Fruit: sugar 1:1 (C_1)	Fruit: sugar to maintain 24°B (C_2)	20% sugar (C_3)
R_1 (1:1)	0.013	0.032	0.029	0.012	0.037	0.03
R_2 (1:2)	0.039	0.043	0.02	0.038	0.051	0.021
R_3 (1:0.07)	0.016	0.019	0.045	0.018	0.034	0.046
Mean R	R_1 = 0.025		R_2 = 0.035		R_3 = 0.03	
Mean C	C_1 = 0.022		C_2 = 0.036		C_3 = 0.032	
Mean N	N_1 = 0.035			N_2 = 0.032		
CD (0.05)	R= 0.002		C= 0.004	N= NS	R×C×N= 0.004	

Fermentation efficiency (%)

The highest fermentation efficiency (228.08%) was recorded when fruit: water ratio was 1:0.07 and lowest (154.43%) was recorded when 1:2 fruit: water ratio was adopted (Table 13).

Highest fermentation efficiency (230.95%) was recorded when fruit: sugar ratio was maintained at 20% sugar and lowest (163.4%) was recorded when 1:1 fruit: sugar ratio was adopted.

There was no significant difference between the fermentation efficiency of wines prepared with and without nitrogen source.

When the interaction effect was considered, the highest fermentation efficiency (310.63%) was recorded in the papaya wine produced using 1:0.07 fruit: water ratio, 1:1 fruit: sugar ratio and without nitrogen source. This was on par with the wine prepared with 1:2 fruit: water ratio, 20% sugar and with nitrogen source (276.34%). The lowest fermentation efficiency (56.20%) was recorded in wine produced with 1:2 fruit: water ratio, 1:1 fruit: sugar ratio and without nitrogen source. This was on par with the wine produced in same manner but with nitrogen source (58.03%) and wine produced with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio and with nitrogen source (92.91%).

Yield (%)

The highest yield (85.95%) was recorded when fruit: water ratio was 1:2 and the lowest content (62%) was recorded when 1:0.07 fruit: water ratio was adopted (Table 14).

Highest yield (82.02%) was observed in wines produced when fruit: sugar ratio was maintained at 1:1 and the lowest (50.77%) was recorded when 20% sugar was adopted.

Higher yield (73.52%) was recorded for wines prepared with nitrogen source and the lower (70.44%) was recorded in wines produced without nitrogen source.

Table 13. Effect of process parameters on fermentation efficiency of papaya wines

Fermentation efficiency (%)						
Fruit water ratio (R)	With nitrogen source (N_1)			Without nitrogen source (N_2)		
	Fruit: sugar 1:1 (C_1)	Fruit: sugar to maintain 24°B (C_2)	20% sugar (C_3)	Fruit: sugar 1:1 (C_1)	Fruit: sugar to maintain 24°B (C_2)	20% sugar (C_3)
R_1 (1:1)	92.91	171.76	222.32	221.41	179.22	216.20
R_2 (1:2)	58.03	149.69	276.34	56.20	145.96	240.4
R_3 (1:0.07)	241.18	244.35	207.63	310.63	141.84	222.47
Mean R	R_1 = 183.97		R_2 = 154.43		R_3 = 228.08	
Mean C	C_1 = 163.4		C_2 = 172.14		C_3 = 230.95	
Mean N	N_1 = 184.95			N_2 = 192.71		
CD (0.05)	R= 47.98		C= 30.78	N= NS	R×C×N= 47.56	

Table 14. Effect of process parameters on yield of papaya wines

Yield (%)												
Fruit water ratio (R)	With nitrogen source (N_1)						Without nitrogen source (N_2)					
	Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°Brix (C_2)		20% sugar (C_3)		Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°Brix (C_2)		20% sugar (C_3)	
	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2
R_1 (1:1)	84	87	57	42.7	*	*	81.7	74	83.7	73.7	*	*
R_2 (1:2)	90.7	87.3	82.3	87	*	*	74.7	86	89.3	90.3	*	*
R_3 (1:0.07)	86	77.67	62.4	68.4	55.3	61.5	78.7	76.5	44.98	46.27	42.2	44.1
Mean R	R_1= 72.97				R_2= 85.95				R_3= 62			
Mean C	C_1= 82.02				C_2= 69.00				C_3= 50.77			
Mean N	N_1= 73.52						N_2= 70.44					
Mean Cl	Cl_1= 72.35						Cl_2= 71.6					
CD (0.05)	R= 0.36			C= 0.47		N= 0.31			Cl= 0.19		R×C×N×Cl= 0.65	

*- Contaminated; Cl_1 – Clarification using pectinase; Cl_2 – Clarification by settling

Higher yield (72.35%) was recorded for wines clarified using pectinase compared to wines clarified by settling (71.6%).

When the interaction effect was considered, the highest yield (90.7%) was noticed in papaya wine produced using 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase. This was on par with the wine produced with 1:2 fruit: water ratio, maintaining 24° brix, without nitrogen source and clarified by settling (90.3%). The lowest yield (42.2%) was recorded in the wine prepared with 1:0.07 fruit: water ratio, 20% sugar, without nitrogen source and clarified by pectinase. This was on par with the wine prepared using 1:1 fruit: water ratio, maintaining 24° brix, with nitrogen source and clarified by settling (42.7%).

The following four wines were contaminated after primary fermentation.

1. Wines prepared with 1:1 fruit: water ratio, 20% sugar and with nitrogen source
2. Wines prepared with 1:1 fruit: water ratio, 20% sugar and without nitrogen source
3. Wines prepared with 1:2 fruit: water ratio, 20% sugar and with nitrogen source
4. Wines prepared with 1:2 fruit: water ratio, 20% sugar and without nitrogen source

4.2.2.2. Chemical quality

The chemical quality parameters of the prepared papaya wines were recorded after secondary fermentation and presented in the Tables 15-21.

TSS (°Brix)

There was significant difference between the TSS content of different papaya wines (Table 15).

The highest TSS content (22° brix) was recorded when fruit: water ratio was 1:0.07 and the lowest content (9.65° brix) was recorded when 1:2 fruit: water ratio was adopted.

Table 15. Effect of process parameters on TSS of papaya wines

TSS (°Brix)												
Fruit water ratio (R)	With nitrogen source (N_1)						Without nitrogen source (N_2)					
	Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°B (C_2)		20% sugar (C_3)		Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°B (C_2)		20% sugar (C_3)	
	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2
R_1 (1:1)	26.8	26	8	5.8	*	*	26.9	26.4	6.2	5	*	*
R_2 (1:2)	12.4	12.2	7.4	7	*	*	12.8	11.8	7.2	6.4	*	*
R_3 (1:0.07)	48	48.8	13.8	7	9	7	49.2	49.2	8.8	6.4	9.6	7.2
Mean R	R_1=16.39				R_2=9.65				R_3=22			
Mean C	C_1=29.21				C_2=7.42				C_3=8.19			
Mean N	N_1=17.08						N_2=16.65					
Mean Cl	Cl_1=17.58						Cl_2=16.15					
CD (0.05)	R= 0.22		C= 0.28			N= 0.39			Cl= 0.38		R×C×N×Cl= 0.50	

*- contaminated; Cl_1 – Clarification using pectinase; Cl_2 – Clarification by settling

Highest TSS content (29.21° brix) was observed in wines produced when fruit: sugar ratio was maintained at 1:1 and the lowest (7.42° brix) was recorded when fruit: sugar ratio was maintained at 24° brix.

Higher TSS content (17.08° brix) was obtained in wines prepared with nitrogen source and the lower (16.65° brix) was recorded in wines produced without nitrogen source.

Higher TSS content (17.58° brix) was recorded when wines were clarified by pectinase and the lower (16.15° brix) TSS was observed in wines clarified by settling.

When the interaction effect was considered, the highest TSS content (49.2° brix) was in papaya wine produced using 1:0.07 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by pectinase. The wine prepared with same manner but clarified by settling had same TSS content of 49.2° brix. The lowest TSS content (5° brix) was recorded in the wine prepared with 1:1 fruit: water ratio, maintaining 24° brix, without nitrogen source and clarified by settling.

Acidity (%)

Fruit: water ratio, fruit: sugar ratio, nitrogen source and clarification methods did not influence the acidity content of wines significantly (Table 16).

Sugar content (g 100g^{-1})

Reducing sugar (g 100g^{-1})

Reducing sugar content of different papaya wines were significantly influenced by fruit: water ratio and fruit: sugar ratio (Table 17).

The highest reducing sugar was recorded (18.16 g 100g^{-1}) when fruit: water ratio was 1:0.07 and the lowest (4.98 g 100g^{-1}) was recorded when 1:2 fruit: water ratio was adopted.

Highest reducing sugar (27.10 g 100g^{-1}) was recorded when fruit: sugar ratio was maintained at 1:1 and the lowest (1.73 g 100g^{-1}) was recorded when sugar concentration was maintained at 24° brix.

Table 16. Effect of process parameters on acidity of papaya wines

Acidity (%)												
Fruit water ratio (R)	With nitrogen source (N_1)						Without nitrogen source (N_2)					
	Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°B (C_2)		20% sugar (C_3)		Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°B (C_2)		20% sugar (C_3)	
	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2
R_1 (1:1)	0.6	0.5	0.4	0.5	*	*	0.7	1.4	0.4	0.4	*	*
R_2 (1:2)	0.6	0.6	0.4	0.4	*	*	0.4	0.4	0.4	0.4	*	*
R_3 (1:0.07)	0.5	0.5	0.6	0.5	0.6	0.6	0.4	0.6	0.6	0.5	0.6	0.5
Mean R	R_1=0.6				R_2=0.4				R_3=0.5			
Mean C	C_1=0.6				C_2=0.4				C_3=0.5			
Mean N	N_1=0.5					N_2=0.5						
Mean Cl	Cl_1=0.5					Cl_2=0.5						
CD (0.05)	R= NS		C= NS		N= NS			Cl= NS		R×C×N×Cl= NS		

*- contaminated; Cl_1 – Clarification using pectinase; Cl_2 – Clarification by settling

Table 17. Effect of process parameters on reducing sugar of papaya wines

Reducing sugar content (g100g^{-1})												
Fruit water ratio (R)	With nitrogen source (N_1)						Without nitrogen source (N_2)					
	Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°B (C_2)		20% sugar (C_3)		Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°B (C_2)		20% sugar (C_3)	
	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2
R_1 (1:1)	20.03	20.41	2.57	1.37	*	*	27.05	23.81	1.44	1.01	*	*
R_2 (1:2)	8.33	8.77	1.47	1.67	*	*	8.62	8.12	1.59	1.31	*	*
R_3 (1:0.07)	43.56	55.56	2.70	1.09	1.35	3.82	41.95	59.03	1.36	3.17	1.37	2.97
Mean R	R_1=12.21				R_2=4.98				R_3=18.16			
Mean C	C_1=27.10				C_2=1.73				C_3=2.38			
Mean N	N_1=12.33						N_2=13.05					
Mean Cl	Cl_1=11.67						Cl_2=13.72					
CD (0.05)	R= 1.32		C= 1.63		N= NS		Cl= NS		R×C×N×Cl= 2.97			

*- contaminated; Cl_1 – Clarification using pectinase; Cl_2 – Clarification by settling

Reducing sugar content was not significantly influenced by nitrogen source and clarification methods.

When the interaction effect was considered, the highest reducing sugar (59.03 g $100g^{-1}$) was recorded in the papaya wine prepared with 1:0.07 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by settling. The lowest reducing sugar (1.01 g $100g^{-1}$) was observed in wine produced with 1:1 fruit: water ratio, maintaining 24° brix, without nitrogen source and clarified by settling. This was on par with all wines except those produced using 1:1 fruit: sugar ratio, irrespective of fruit: water ratio, nitrogen source and clarification methods.

Total sugar (g $100g^{-1}$)

There was significant difference between the total sugar content of different papaya wines (Table 18).

The highest total sugar (42.48 g $100g^{-1}$) was recorded when 1:0.07 fruit: water ratio was adopted and the lowest (10.60 g $100g^{-1}$) was recorded with 1:2 fruit: water ratio.

Highest total sugar (60.97 g $100g^{-1}$) was recorded when fruit: sugar ratio was maintained at 1:1 and the lowest (4.12 g $100g^{-1}$) was recorded when sugar was maintained at 24° brix.

The higher total sugar (29.66 g $100g^{-1}$) was obtained in wine produced without nitrogen source and the lower (28.03 g $100g^{-1}$) total sugar was obtained with addition of nitrogen source.

Higher total sugar (30.40 g $100g^{-1}$) was recorded when wine was clarified by settling and the lower (27.28 g $100g^{-1}$) content was recorded when clarified using pectinase.

When the interaction effect was studied, the highest total sugar (149.29 g $100g^{-1}$) was observed in wine prepared with 1:0.07 fruit: water ratio, 1:1 fruit: sugar ratio, without addition of nitrogen source and clarified by settling. The lowest total sugar (2.38 g $100g^{-1}$) was observed in wine produced with

Table 18. Effect of process parameters on total sugar of papaya wines

Total sugar content (g100g^{-1})												
Fruit water ratio (R)	With nitrogen source (N_1)						Without nitrogen source (N_2)					
	Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°B (C_2)		20% sugar (C_3)		Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°B (C_2)		20% sugar (C_3)	
	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2
R_1 (1:1)	51.81	50.76	7.44	2.76	*	*	46.73	47.39	3.78	2.38	*	*
R_2 (1:2)	17.67	18.28	3.98	2.76	*	*	18.08	17.21	4.12	2.68	*	*
R_3 (1:0.07)	95.31	119.05	7.87	2.48	8.78	3.44	100.04	149.29	5.89	3.31	10.47	3.86
Mean R	R_1=26.63				R_2=10.60				R_3=42.48			
Mean C	C_1=60.97				C_2=4.12				C_3=6.64			
Mean N	N_1=28.03						N_2=29.66					
Mean Cl	Cl_1=27.28						Cl_2=30.40					
CD (0.05)	R= 1.61		C= 1.40		N= 1.59		Cl= 1.57		R×C×N×Cl=2.25			

*- contaminated; Cl_1 – Clarification using pectinase; Cl_2 – Clarification by settling

1:1 fruit: water ratio, maintaining 24° brix, without nitrogen source and clarified by settling. This was on par with the wine produced in same manner, but clarified by pectinase (3.78 g 100g^{-1}) and the wine produced with 1:1 fruit: water ratio, maintaining 24° brix and clarification by settling, but with nitrogen source (2.76 g 100g^{-1}). Wines prepared with 1:2 fruit: water ratio, maintaining 24° brix, with and without nitrogen source irrespective of clarification methods and the wines which were produced with 1:0.07 fruit: water ratio, maintaining 24° brix or 20% sugar, irrespective of nitrogen source and clarified by settling were also on par.

Alcohol content (%)

Alcohol content of wines was significantly influenced by fruit: water ratio, fruit: sugar ratio and nitrogen source and interaction with nitrogen source and clarification methods (Table 19).

The highest alcohol content (10.99%) was recorded when fruit: water ratio was 1:0.07 and the lowest (10.22%) was recorded when 1:1 fruit: water ratio was adopted.

Highest alcohol content (13.32%) was recorded when sugar was maintained at 24° brix and the lowest (7.89%) was recorded when 1:1 fruit: sugar ratio was adopted.

The alcohol content was higher (11.35%) in wines produced without nitrogen source and the lower content (9.81%) was recorded in wines prepared with nitrogen source.

The alcohol content was highest (16.7%) in papaya wine prepared with 1:1 fruit: water ratio, maintaining 24° brix, without nitrogen source and clarified by pectinase and the wines produced using 1:2 fruit: water ratio, maintaining 24° brix and clarified by settling irrespective of nitrogen source. This was on par with wine produced using 1:2 fruit: water ratio, maintaining 24° brix, without nitrogen source and clarified by pectinase (15.82%). The lowest alcohol content (3.52%) was recorded in the wine produced using fruit: water ratio of 1:1, fruit: sugar ratio of 1:1, with nitrogen source and clarified by pectinase. This was on par with wine produced in the same manner but clarified by settling (4.39%). Wines produced using 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase (5.13%) or by settling (5.27%) and wines with 1:2 fruit: water ratio, 1:1 fruit: sugar ratio,

Table 19. Effect of process parameters on alcohol content of papaya wines

Alcohol content (%)												
Fruit water ratio (R)	With nitrogen source (N_1)						Without nitrogen source (N_2)					
	Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°B (C_2)		20% sugar (C_3)		Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°B (C_2)		20% sugar (C_3)	
	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2
R_1 (1:1)	3.52	4.39	10.55	14.94	*	*	9.89	7.69	16.7	14.06	*	*
R_2 (1:2)	5.13	5.27	13.18	16.7	*	*	4.65	5.13	15.82	16.7	*	*
R_3 (1:0.07)	9.89	11.72	9.34	10.99	11.23	10.55	13.18	14.28	9.89	10.99	10.55	9.34
Mean R	R_1=10.22				R_2=10.32				R_3=10.99			
Mean C	C_1=7.89				C_2=13.32				C_3=10.42			
Mean N	N_1=9.81						N_2=11.35					
Mean Cl	Cl_1=10.25						Cl_2=10.91					
CD (0.05)	R= 0.87		C= 1.52			N= 1.32		Cl= NS		R×C×N×Cl= 1.51		

*- contaminated; Cl_1 – Clarification using pectinase; Cl_2 – Clarification by settling

1:1 fruit: sugar ratio, without nitrogen source and clarified by pectinase (4.65%) or by settling (5.13%) were also on par.

Polyphenol content (mgg^{-1})

Polyphenol content of wines was significantly influenced by fruit: water ratio, fruit: sugar ratio, nitrogen source, clarification methods and their interaction (Table 20).

The lowest polyphenol content (49.58mgg^{-1}) was recorded when 1:2 fruit: water ratio was used and the highest (66.44 mgg^{-1}) was recorded in wines produced with 1:1 fruit: water ratio.

Lowest polyphenol content (43.90mgg^{-1}) was observed when fruit: sugar ratio was maintained at 20% sugar and highest (61.69mgg^{-1}) was observed with 1:1 fruit: sugar ratio.

The lower polyphenol content (53.02mgg^{-1}) was recorded in wines produced without nitrogen source compared to wines produced with nitrogen source (60.87mgg^{-1}).

The polyphenol content was lower in wines clarified by settling (55.28mgg^{-1}) compared to wines clarified using pectinase (58.61mgg^{-1}).

When the interaction effect was studied, the lowest polyphenol content (28.4mgg^{-1}) was recorded when wine was produced with 1:0.07 fruit: water ratio, 20% sugar, without nitrogen source and clarified using pectinase. Polyphenol content was highest (106.83mgg^{-1}) in the wine prepared with 1:1 fruit: water ratio, maintaining 24° brix, with nitrogen source and clarified by pectinase.

Antioxidant activity (%)

There was significant difference between the antioxidant activity of different papaya wines (Table 21).

The highest antioxidant activity (75.96%) was recorded when 1:1 fruit: water ratio was employed and the lowest (39.97%) was recorded when 1:0.07 fruit: water ratio was adopted.

Table 20. Effect of process parameters on polyphenol content of papaya wines

Polyphenol content (mgg^{-1})												
Fruit water ratio (R)	With nitrogen source (N_1)						Without nitrogen source (N_2)					
	Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°B (C_2)		20% sugar (C_3)		Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°B (C_2)		20% sugar (C_3)	
	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2
R_1 (1:1)	83.65	50.19	106.83	59.65	*	*	62.51	52.74	68.46	47.46	*	*
R_2 (1:2)	56.55	56.28	43.15	62.46	*	*	46.64	60.83	35.65	35.1	*	*
R_3 (1:0.07)	50.46	72.51	49.46	48.65	59.06	53.34	66.18	81.74	63.55	58.2	28.4	34.81
Mean R	R_1=66.44				R_2=49.58				R_3=55.53			
Mean C	C_1=61.69				C_2=56.55				C_3=43.90			
Mean N	N_1=60.87						N_2=53.02					
Mean Cl	Cl_1=58.61						Cl_2=55.28					
CD (0.05)	R= 0.09		C= 1.08		N= 0.23			Cl= 0.06		R×C×N×Cl= 0.15		

*- contaminated; Cl_1 – Clarification using pectinase; Cl_2 – Clarification by settling

Table 21. Effect of process parameters on antioxidant activity of papaya wines

Antioxidant activity (% inhibition)												
Fruit water ratio (R)	With nitrogen source (N_1)						Without nitrogen source (N_2)					
	Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°B (C_2)		20% sugar (C_3)		Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°B (C_2)		20% sugar (C_3)	
	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2
R_1 (1:1)	86.54	86.93	67.05	76.93	*	*	87.57	86.67	45.51	70.51	*	*
R_2 (1:2)	82.95	82.69	52.69	82.31	*	*	63.2	82.82	35.64	55.26	*	*
R_3 (1:0.07)	24.88	66.93	62.31	61.54	31.41	27.18	36.93	60.39	40.51	35.64	12.44	19.48
Mean R	R_1=75.96				R_2=67.19				R_3=39.97			
Mean C	C_1=70.71				C_2=57.16				C_3=22.63			
Mean N	N_1=63.74						N_2=52.33					
Mean Cl	Cl_1=52.12						Cl_2=63.95					
CD (0.05)	R= 0.42		C= 0.54		N= 0.61			Cl= 0.73		R×C×N×Cl= 0.66		

*- contaminated; Cl_1 – Clarification using pectinase; Cl_2 – Clarification by settling

Highest antioxidant activity (70.71%) was observed when fruit: sugar ratio was maintained at 1:1 and the lowest (22.63%) was observed when 20% sugar was adopted.

Significantly higher antioxidant activity was recorded (63.74%) when wines were prepared with nitrogen source compared to wines produced without nitrogen source (52.33%).

Higher antioxidant activity (63.95%) was recorded in wines clarified by settling compared to wines clarified using pectinase (52.12%).

When the interaction effect was examined, the antioxidant activity was highest (87.57%) in the wine prepared with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified using pectinase. This wine was on par with the wine produced in the same manner, but with nitrogen source and clarified by settling (86.93%). The lowest antioxidant activity (12.44%) was recorded in the wine produced using 1:0.07 fruit: water ratio, 20% sugar, without addition of nitrogen source and clarified by pectinase.

4.2.2.3. Sensory quality

Sensory quality parameters of wines were recorded after completion of secondary fermentation. There was significant difference in the sensory quality parameters of wines except for aroma (Table 22).

Appearance

Mean score for appearance of papaya wines varied between 1.8 to 2.9. The papaya wines produced using 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase had the highest mean score (2.9) for appearance. The same score was obtained for the wines prepared with 1:1 or 1:2 fruit: water ratio, maintaining 24° brix or 1:1 fruit: sugar ratio, with addition of nitrogen source and clarified by pectinase. This was followed by the wines prepared using fruit: water ratio of 1:1, maintaining 24° brix, without nitrogen source and clarified using pectinase (2.8) and wines with 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by pectinase (2.8). The wines prepared with fruit: water ratio of 1:1, fruit: sugar ratio of 1:1, with or without nitrogen source and clarified by settling had the lowest mean score for appearance (1.8). Fruit: water ratio of 1:0.07, fruit: sugar ratio of 1:1, without nitrogen source and clarification done by settling also resulted in wines with least mean score for appearance (1.8).

Aroma

Different process parameters did not significantly influence the aroma of different wines. However, the mean score of aroma varied from 3.3 to 4.7.

Taste/Texture

Mean score for taste/texture of wines ranged from 1.3 to 5.0. The wines produced using 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase had the highest mean score for taste/texture (5.0) , which was followed by the wines prepared with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified using settling and wines prepared with 1:2 fruit: water ratio, maintaining 24° brix, with nitrogen source and clarified by settling (4.7). The lowest mean score for taste/texture (1.3) was obtained for the wine prepared using 1:1 fruit: water ratio, maintaining 24° brix, without nitrogen source and clarified by pectinase.

After taste

Mean score for after taste of papaya wines ranged between 0.65 to 2.8. The highest mean score for aftertaste (2.8) was obtained for the wine produced using 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase. This was followed by the wine produced using 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by settling (2.4). Wine produced using 1:1 fruit: water ratio, maintaining 24° brix, without nitrogen source and clarified by settling had the lowest mean score for after taste (0.65).

Overall impression

Mean score for overall impression of papaya wines varied from 0.5 to 2.0. The wines produced using 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase had the highest mean score for overall impression (2.0),

Table 22. Effect of process parameters on sensory quality of papaya wines

Treatments	Appearance		Aroma		Taste/Texture		After taste		Overall impression	
	Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank
T_1 –1:1 F-W+1:1 F-S+N_1+Cl_1	2.9	224.50	4.4	159.50	5.0	211.80	2.8	235.20	2.0	240.50
T_2–1:1 F-W+1:1 F-S+N_1+Cl_2	2.2	142.80	4.3	158.00	4.6	190.60	2.3	188.80	1.6	183.30
T_3 –1:1 F-W+1:1 F-S+N_2+Cl_1	2.5	169.55	4.5	169.15	4.5	181.15	2.2	183.80	1.5	172.65
T_4 –1:1 F-W+1:1 F-S+N_2+Cl_2	1.8	88.35	4.1	140.70	4.7	198.00	2.4	195.80	1.8	205.55
T_5 –1:1 F-W+24°Brix+N_1+Cl_1	2.9	224.50	3.8	121.70	1.9	47.35	0.75	42.50	0.7	59.70
T_6 –1:1 F-W+24°Brix+N_1+Cl_2	1.9	102.40	3.6	110.90	1.7	38.25	0.7	38.70	0.5	49.10
T_7 –1:1 F-W+24°Brix+N_2+Cl_1	2.8	212.00	3.6	117.30	1.3	23.25	0.8	52.25	0.8	74.00
T_8 –1:1 F-W+24°Brix+N_2+Cl_2	2.1	122.45	3.3	91.50	1.5	29.75	0.65	43.60	0.5	48.25
T_9 –1:2 F-W+1:1 F-S+N_1+Cl_1	2.9	224.50	4.7	188.65	4.5	180.40	2.1	175.05	1.5	174.60
T_{10} –1:2 F-W+1:1 F-S+N_1+Cl_2	2.1	130.30	3.8	125.90	3.6	134.95	1.7	135.65	1.3	146.00
T_{11} –1:2 F-W+1:1 F-S+N_2+Cl_1	2.8	207.05	4.3	158.85	4.2	161.75	1.8	138.60	1.3	146.00
T_{12} –1:2 F-W+1:1 F-S+N_2+Cl_2	1.9	105.30	4.0	133.35	3.7	127.90	1.6	118.75	1.1	117.40
T_{13} –1:2 F-W+24°Brix+N_1+Cl_1	1.9	103.25	4.4	157.00	3.9	148.75	1.8	138.60	1.2	125.35
T_{14} –1:2 F-W+24°Brix+N_1+Cl_2	1.8	95.70	4.2	149.50	4.7	192.95	2.2	173.80	1.6	176.95
T_{15} –1:2 F-W+24°Brix+N_2+Cl_1	2.2	134.80	4.2	145.00	3.5	122.35	2.0	156.90	1.2	120.90
T_{16} –1:2 F-W+24°Brix+N_2+Cl_2	1.9	100.85	4.1	134.70	4.2	164.55	2.0	156.80	1.4	149.95
T_{17} –1:0.07 F-W+1:1 F-S+N_1+Cl_1	2.1	125.55	4.2	153.70	4.4	177.95	2.1	165.00	1.5	166.05
T_{18} –1:0.07 F-W+1:1 F-S+N_1+Cl_2	2.0	124.75	4.1	147.20	4.1	165.40	2.2	180.00	1.4	151.75
T_{19} –1:0.07 F-W+1:1 F-S+N_2+Cl_1	2.0	125.55	4.2	156.10	4.2	171.40	2.2	177.70	1.5	166.05
T_{20} –1:0.07 F-W+1:1 F-S+N_2+Cl_2	1.8	92.80	4.2	145.00	4.2	164.90	1.9	145.20	1.3	146.00
T_{21} –1:0.07 F-W+24°Brix+N_1+Cl_1	2.1	125.95	4.0	125.20	3.7	125.85	1.6	122.30	1.1	120.05
T_{22} –1:0.07 F-W+24°Brix+N_1+Cl_2	2.2	129.65	3.6	102.85	3.7	129.55	1.7	131.75	1.2	125.95
T_{23} –1:0.07 F-W+24°Brix+N_2+Cl_1	2.2	128.35	3.9	122.75	3.8	134.30	1.8	140.65	1.3	145.95
T_{24} –1:0.07 F-W+24°Brix+N_2+Cl_2	2.3	142.45	4.0	126.20	3.7	139.00	1.8	136.85	1.2	124.30
T_{25} –1:0.07 F-W+20% Sugar+N_1+Cl_1	2.1	134.80	4.1	143.35	3.8	135.25	1.6	117.20	1.2	139.50
T_{26} –1:0.07 F-W+20% Sugar+N_1+Cl_2	2.0	125.20	4.0	131.40	3.9	143.15	1.9	150.55	1.5	161.55
T_{27} –1:0.07 F-W+20% Sugar+N_2+Cl_1	2.3	148.80	4.4	163.15	3.2	139.00	1.9	151.65	1.3	151.00
T_{28} –1:0.07 F-W+20% Sugar+N_2+Cl_2	2.2	141.85	4.3	155.40	4.0	154.50	1.8	140.35	1.3	145.65
K value	79.70		20.24		106.72		99.12		87.22	
χ^2	40.113									

F-W – Fruit: water ratio; F-S – Fruit: sugar ratio; N_1 – With nitrogen source; N_2 – Without nitrogen source; Cl_1 – Clarified by pectinase; Cl_2 – Clarified by settling

which was followed by the wine prepared with fruit: water ratio of 1:1, fruit: sugar ratio 1:1, without nitrogen source and clarified using settling (1.8). The lowest mean score for overall impression (0.5) was obtained for the wines prepared using 1:1 fruit: water ratio, maintaining 24° brix, with or without nitrogen source and clarification done by settling.

4.2.3 Rose apple

4.2.3.1. Physical quality

The physical quality parameters viz., rate of fermentation and fermentation efficiency of 18 different rose apple wines were recorded immediately after primary fermentation and presented in Tables 23-24.

Rate of fermentation (°Brix/24 hours)

There was no significant difference between the rate of fermentation of wines prepared with different fruit: water ratios and nitrogen source (Table 23).

The highest rate of fermentation (0.029°Brix/24 hours) was recorded when fruit: sugar ratio was maintained at 24° brix and the lowest rate (0.017°Brix/24 hours) was recorded when 20% sugar was adopted.

When the interaction effect was considered, the highest rate of fermentation (0.039°Brix/24 hours) was recorded in the rose apple wines produced using 1:2 fruit: water ratio, 1:1 fruit: sugar ratio and with nitrogen source. This was on par with the wine produced in same manner but without addition of nitrogen source (0.038°Brix/24 hours). The lowest rate of fermentation (0.013°Brix/24 hours) was recorded in wines produced with 1:0.07 fruit: water ratio, 20% sugar and with or without nitrogen source.

Fermentation efficiency (%)

Fermentation efficiency was significantly influenced by fruit: water ratio, fruit: sugar ratio, and their interaction with nitrogen source (Table 24).

Table 23. Effect of process parameters on rate of fermentation of rose apple wines

Rate of fermentation (°B/24 hours)						
Fruit water ratio (R)	With nitrogen source (N_1)			Without nitrogen source (N_2)		
	Fruit: sugar 1:1 (C_1)	Fruit: sugar to maintain 24° brix (C_2)	20% sugar (C_3)	Fruit: sugar 1:1 (C_1)	Fruit: sugar to maintain 24° brix (C_2)	20% sugar (C_3)
R_1 (1:1)	0.017	0.033	0.024	0.022	0.034	0.024
R_2 (1:2)	0.039	0.03	0.014	0.038	0.034	0.014
R_3 (1:0.07)	0.017	0.019	0.013	0.016	0.02	0.013
Mean R	$R_1 = 0.025$		$R_2 = 0.028$		$R_3 = 0.016$	
Mean C	$C_1 = 0.025$		$C_2 = 0.029$		$C_3 = 0.017$	
Mean N	$N_1 = 0.025$		$N_2 = 0.022$			
CD (0.05)	R= NS	C= 0.002		N= NS	R×C×N= 0.003	

Table 24. Effect of process parameters and fermentation efficiency of rose apple wines

Fermentation efficiency (%)						
Fruit water ratio (R)	With nitrogen source (N_1)			Without nitrogen source (N_2)		
	Fruit: sugar 1:1 (C_1)	Fruit: sugar to maintain 24° brix (C_2)	20% sugar (C_3)	Fruit: sugar 1:1 (C_1)	Fruit: sugar to maintain 24° brix (C_2)	20% sugar (C_3)
R_1 (1:1)	71.91	95.2	174.63	56.66	92.92	170.34
R_2 (1:2)	43.44	128.17	255.13	40.72	109.05	235.49
R_3 (1:0.07)	237.54	159.46	257.97	263.96	150.44	234.72
Mean R	R_1 = 110.25		R_2 = 135.31		R_3 = 217.35	
Mean C	C_1 = 119.04		C_2 = 122.52		C_3 = 221.38	
Mean N	N_1 = 158.16			N_2 = 150.48		
CD (0.05)	R= 20.22	C= 13.49		N= NS	R×C×N= 27.60	

The highest fermentation efficiency (217.35%) was recorded when fruit: water ratio was 1:0.07 and lowest fermentation efficiency (110.25%) was recorded when 1:1 fruit: water ratio was adopted.

Highest fermentation efficiency (221.38%) was recorded when fruit: sugar ratio was maintained at 20% sugar and lowest (119.04%) was recorded in wines prepared with 1:1 fruit: sugar ratio.

There was no significant difference between the fermentation efficiency of wines prepared with and without nitrogen source.

When the interaction effect was considered, the highest fermentation efficiency (263.96%) was recorded in the rose apple wine produced using 1:0.07 fruit: water ratio, 1:1 fruit: sugar ratio and without nitrogen source. This was on par with the wine produced in same manner but with nitrogen source (237.54%). Wines produced using 1:2 or 1:0.07 fruit: water ratio, 20% sugar and with nitrogen source were also on par. The lowest fermentation efficiency (40.72%) was recorded in wine produced with 1:2 fruit: water ratio, 1:1 fruit: sugar ratio and without nitrogen source. This was on par with the wines produced in same manner but with nitrogen source (43.44%) and wines with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio and without nitrogen source (56.66%).

Yield (%)

The highest yield (89.29%) was recorded when fruit: water ratio was 1:2 and the lowest content (86.44%) was recorded when 1:0.07 fruit: water ratio was adopted (Table 25).

Highest yield (88.43%) was observed in wines produced when fruit: sugar ratio was maintained at 24° brix and the lowest (87.2%) was recorded when 20% sugar was adopted.

Higher yield (87.96%) was recorded for wines prepared with nitrogen source and the lower (87.94%) was recorded in wines produced without nitrogen source.

Table 25. Effect of process parameters on yield of rose apple wines

Yield (%)												
Fruit water ratio (R)	With nitrogen source (N_1)						Without nitrogen source (N_2)					
	Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°Brix (C_2)		20% sugar (C_3)		Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°Brix (C_2)		20% sugar (C_3)	
	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2
R_1 (1:1)	91.33	86.33	90.33	91.67	*	*	83	92.33	83.33	93	*	*
R_2 (1:2)	87.33	93.33	87.33	92.33	*	*	83.67	93.33	85	92	*	*
R_3 (1:0.07)	82.24	87	86.42	87.24	84	84.8	84.67	88.33	85.48	87.09	89.6	90.4
Mean R	R_1= 88.91				R_2= 89.29				R_3= 86.44			
Mean C	C_1= 87.74				C_2= 88.43				C_3= 87.2			
Mean N	N_1= 87.96						N_2= 87.94					
Mean Cl	Cl_1= 85.98						Cl_2= 89.94					
CD (0.05)	R= 1.25		C= 0.84			N= 0.99			Cl= 1.22		R×C×N×Cl= 3.21	

*- Contaminated; Cl_1 – Clarification using pectinase; Cl_2 – Clarification by settling

Higher yield (89.94%) was recorded for wines clarified by settling compared to wines clarified using pectinase (85.98%).

When the interaction effect was considered, the highest yield (93.33%) was noticed in rose apple wine produced using 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by settling. The same yield was recorded in the wine produced in same manner but without nitrogen source (93.33%). This was on par with the wines produced in same manner but maintaining 24° brix and with (92.33%) or without (92%) nitrogen source. Wine produced with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase (91.33%), wine produced with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by settling (92.33%), wine produced using 1:1 fruit: water ratio, maintaining 24° brix, with nitrogen source and clarified by pectinase (90.33%) or by settling (91.67%) and wine produced using 1:1 fruit: water ratio, maintaining 24° brix, without nitrogen source and clarified by settling (93%) were also on par. The lowest yield (82.24%) was recorded in the wine prepared with 1:0.07 fruit: water ratio, 20% sugar, with nitrogen source and clarified by pectinase.

The following four wines were contaminated after primary fermentation.

1. Wines prepared with 1:1 fruit: water ratio, 20% sugar and with nitrogen source
2. Wines prepared with 1:1 fruit: water ratio, 20% sugar and without nitrogen source
3. Wines prepared with 1:2 fruit: water ratio, 20% sugar and with nitrogen source
4. Wines prepared with 1:2 fruit: water ratio, 20% sugar and without nitrogen source

4.2.3.2. Chemical quality

The chemical quality parameters of the prepared rose apple wines were recorded after secondary fermentation and presented in the Tables 26-32.

TSS (°Brix)

There was significant difference between the TSS content of different rose apple wines (Table 26).

The highest TSS content (21.13° brix) was recorded when fruit: water ratio was 1:0.07 and the lowest content (7.32° brix) was recorded when 1:2 fruit: water ratio was adopted.

Highest TSS content (28.2° brix) was observed in wines produced when fruit: sugar ratio was maintained at 1:1 and the lowest (6.1° brix) was recorded when 20% sugar was adopted.

Higher TSS content (16.04° brix) was obtained in wines prepared with nitrogen source and the lower (15.38° brix) was recorded in wines produced without nitrogen source.

Higher TSS content (16.28° brix) was recorded when wines were clarified by pectinase and the lower (15.14° brix) was observed in wines clarified by settling.

When the interaction effect was considered, the highest TSS content (49.8° brix) was in rose apple wine produced using 1:0.07 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by pectinase. This was on par with wine produced in same manner but clarified by settling (49.4° brix). The lowest TSS content (4.6° brix) was recorded in the wine prepared with 1:1 fruit: water ratio, maintaining 24° brix, without nitrogen source and clarified by settling. This was on par with wines prepared using 1:2 fruit: water ratio, maintaining 24° brix and clarified by settling irrespective of nitrogen source (5° brix).

Acidity (%)

Acidity content (titratable acidity as citric acid) of wines was significantly influenced by fruit: water ratio, fruit: sugar ratio and their interaction with nitrogen source and clarification methods (Table 27).

The highest acidity content (0.9%) was recorded when fruit: water ratio was 1:0.07 and the lowest (0.7%) was recorded when 1:1 or 1:2 fruit: water ratio was adopted.

Table 26. Effect of process parameters on TSS of rose apple wines

	TSS (°Brix)											
Fruit water ratio (R)	With nitrogen source (N_1)						Without nitrogen source (N_2)					
	Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°B (C_2)		20% sugar (C_3)		Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°B (C_2)		20% sugar (C_3)	
	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2
R_1 (1:1)	27.2	27	7.6	5.4	*	*	25.6	25	5.4	4.6	*	*
R_2 (1:2)	10	9.4	5.4	5	*	*	9.6	8.8	5.4	5	*	*
R_3 (1:0.07)	48.6	48	11	7.6	7.2	5.2	49.8	49.4	8.4	6.4	6.8	5.2
Mean R	R_1=15.97				R_2=7.32				R_3=21.13			
Mean C	C_1=28.2				C_2=6.43				C_3=6.1			
Mean N	N_1=16.04						N_2=15.38					
Mean Cl	Cl_1=16.28						Cl_2=15.14					
CD (0.05)	R= 0.22		C= 0.28		N= 0.14			Cl= 0.13		R×C×N×Cl= 0.51		

*- contaminated; Cl_1 – Clarification using pectinase; Cl_2 – Clarification by settling

Table 27. Effect of process parameters on acidity of rose apple wines

Acidity (%)												
Fruit water ratio (R)	With nitrogen source (N_1)						Without nitrogen source (N_2)					
	Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°B (C_2)		20% sugar (C_3)		Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°B (C_2)		20% sugar (C_3)	
	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2
R_1 (1:1)	0.8	0.7	0.7	0.7	*	*	0.7	0.6	0.6	0.7	*	*
R_2 (1:2)	0.7	0.7	0.8	0.7	*	*	0.6	0.7	0.7	0.7	*	*
R_3 (1:0.07)	0.9	0.8	1.24	0.8	1.01	0.9	0.7	0.6	1.01	0.9	1.01	1.01
Mean R	R_1=0.7				R_2=0.7				R_3=0.9			
Mean C	C_1=0.7				C_2=0.8				C_3=0.9			
Mean N	N_1=0.8						N_2=0.7					
Mean Cl	Cl_1=0.8						Cl_2=0.7					
CD (0.05)	R= 0.12		C= 0.05		N= NS			Cl= NS		R×C×N×Cl = 0.31		

*- contaminated; Cl_1 – Clarification using pectinase; Cl_2 – Clarification by settling

Highest acidity content (0.9%) was recorded when fruit: sugar ratio was maintained at 20% sugar and the lowest (0.7%) was recorded in wines with 1:1 fruit: sugar ratio.

There was no significant difference between the acidity content of wines prepared with or without nitrogen source and clarification methods.

When the interaction effect was studied, the highest acidity content (1.24%) was obtained for the wine prepared with fruit: water ratio of 1:0.07, maintaining 24° brix, with nitrogen source and clarified using pectinase. This was on par with the wine prepared using 1:0.07 fruit: water ratio, 20% sugar, with nitrogen source and clarified using pectinase (1.01%). The wine prepared with 1:0.07 fruit: water ratio, maintaining 24° brix, without nitrogen source and clarified by pectinase (1.01%) and wines prepared with 1:0.07 fruit: water ratio, 20% sugar and without nitrogen source irrespective of clarification methods were also on par. The lowest acidity content (0.6%) was recorded in the wines produced using fruit: water ratio of 1:1 or 1:0.07, fruit: sugar ratio of 1:1, without nitrogen source and clarified by settling. Wines prepared with 1:1 fruit: water ratio, maintaining 24° brix, without nitrogen source and clarified by pectinase and wines with 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified using pectinase also had 0.6 per cent acidity.

Sugar content (g 100g^{-1})

Reducing sugar (g 100g^{-1})

There was significant difference between the reducing sugar content of different rose apple wines with fruit: water ratio, fruit: sugar ratio and nitrogen source. Clarification methods did not significantly influence the reducing sugar content of wines (Table 28).

The highest reducing sugar was recorded (5.9 g 100g^{-1}) when fruit: water ratio was 1:0.07 and the lowest (2.54 g 100g^{-1}) was recorded when 1:2 fruit: water ratio was adopted.

Highest reducing sugar (9.3 g 100g^{-1}) was recorded in wine when fruit: sugar ratio was maintained at 1:1 and the lowest (0.82 g 100g^{-1}) was recorded in wine produced with 20% sugar.

The higher reducing sugar (4.91 g 100g^{-1}) was obtained in wine produced with nitrogen source and the lower (4.3 g 100g^{-1}) reducing sugar was obtained without addition of nitrogen source.

When the interaction effect was considered, the highest reducing sugar (15.94 g 100g^{-1}) was recorded in the rose apple wine produced with 1:0.07 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by settling. The lowest reducing sugar (0.64 g 100g^{-1}) was observed in wine produced with 1:1 fruit: water ratio, maintaining 24° brix, without nitrogen source and clarified by pectinase. This was on par with wine produced in the same manner but clarified by settling (0.73 g 100g^{-1}). Wines prepared with fruit: water ratio of 1:1 maintaining 24°brix, with nitrogen source and clarified by pectinase (0.98 g 100g^{-1}) and by settling (0.77 g 100g^{-1}) and wines with 1:0.07 fruit: water ratio and 20% sugar irrespective of nitrogen source and clarification methods were also on par.

Total sugar (g 100g^{-1})

There was significant difference between the total sugar content of different rose apple wines prepared using different process variables (Table 29).

The total sugar content was maximum (18.68 g 100g^{-1}) when wine produced with 1:0.07 fruit: water ratio and the least (7.54 g 100g^{-1}) was recorded when 1:2 fruit: water ratio was adopted.

Highest total sugar (24.64 g 100g^{-1}) was recorded when fruit: sugar ratio was maintained at 1:1 and the lowest (4.95g 100g^{-1}) was recorded when sugar was maintained at 24° brix.

The higher total sugar (13.58 g 100g^{-1}) was obtained in wine produced with nitrogen source and the lower (13.30 g 100g^{-1}) total sugar was obtained without addition of nitrogen source.

Table 28. Effect of process parameters on reducing sugar of rose apple wines

Reducing sugar (g100g^{-1})												
Fruit water ratio (R)	With nitrogen source (N_1)						Without nitrogen source (N_2)					
	Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°Brix (C_2)		20% sugar (C_3)		Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°Brix (C_2)		20% sugar (C_3)	
	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2
R_1 (1:1)	11.2	9.17	0.98	0.77	*	*	7.24	7.1	0.64	0.73	*	*
R_2 (1:2)	5.13	3.76	1.22	1.07	*	*	3.71	3.25	1.15	1.04	*	*
R_3 (1:0.07)	14.76	15.94	2.21	1.06	0.72	0.83	15.05	15.32	2.13	1.11	0.94	0.81
Mean R	R_1= 4.73				R_2= 2.54				R_3= 5.9			
Mean C	C_1= 9.3				C_2= 1.18				C_3= 0.82			
Mean N	N_1= 4.91						N_2= 4.3					
Mean Cl	Cl_1= 4.74						Cl_2= 4.42					
CD (0.05)	R= 0.16		C= 0.08			N= 0.09		Cl= NS			R×C×N×Cl= 0.34	

*- contaminated; Cl_1 – Clarification using pectinase; Cl_2 – Clarification by settling

Table 29. Effect of process parameters on total sugar of rose apple wines

Total sugar (g100g^{-1})												
Fruit water ratio (R)	With nitrogen source (N$_1$)						Without nitrogen source (N$_2$)					
	Fruit: sugar 1:1 (C$_1$)		Fruit: sugar to maintain 24°Brix (C$_2$)		20% sugar (C$_3$)		Fruit: sugar 1:1 (C$_1$)		Fruit: sugar to maintain 24°Brix (C$_2$)		20% sugar (C$_3$)	
	Cl$_1$	Cl$_2$	Cl$_1$	Cl$_2$	Cl$_1$	Cl$_2$	Cl$_1$	Cl$_2$	Cl$_1$	Cl$_2$	Cl$_1$	Cl$_2$
R$_1$ (1:1)	21.38	20.16	4.04	3.96	*	*	17.94	17.12	3.44	3.82	*	*
R$_2$ (1:2)	10.76	8.42	5.11	4.87	*	*	13.17	8.03	5.02	4.96	*	*
R$_3$ (1:0.07)	44.12	44.24	6.34	5.81	6.14	4.83	47.26	43.15	6.26	5.77	5.72	4.64
Mean R	R$_1$=11.48				R$_2$=7.54				R$_3$=18.68			
Mean C	C$_1$=24.64				C$_2$=4.95				C$_3$=5.33			
Mean N	N$_1$=13.58						N$_2$=13.30					
Mean Cl	Cl$_1$=14.05						Cl$_2$=12.84					
CD (0.05)	R= 0.12		C= 0.14		N= 0.18			Cl= 0.02		R×C×N×Cl= 0.17		

*- contaminated; Cl$_1$ – Clarification using pectinase; Cl$_2$ – Clarification by settling

Higher total sugar (14.05 g 100g^{-1}) was observed when wine was clarified using pectinase and the lower (12.84 g 100g^{-1}) content was recorded when clarified by settling.

When the interaction effect was studied, the highest total sugar (47.26 g 100g^{-1}) was observed in wine prepared with 1:0.07 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified using pectinase. The lowest total sugar (3.44 g 100g^{-1}) was observed in wine produced with 1:1 fruit: water ratio, maintaining 24° brix, without nitrogen source and clarified using pectinase.

Alcohol content (%)

Alcohol content of wines was significantly influenced by fruit: water ratio, fruit: sugar ratio and their interaction with nitrogen source and clarification methods, whereas nitrogen source and clarification methods did not significantly influence the alcohol content of wines (Table 30).

The highest alcohol content (9.78%) was recorded when fruit: water ratio was 1:0.07 and the lowest (7.03%) was recorded when 1:1 fruit: water ratio was adopted.

Highest alcohol content (10.89%) was recorded when fruit: sugar ratio was maintained at 20% sugar and the lowest (5.85%) was recorded when 1:1 fruit: sugar ratio was adopted.

When the interaction effect was considered, the alcohol content was highest (13.18%) in the rose apple wine prepared with fruit: water ratio of 1:2, maintaining 24° brix, without nitrogen source and clarified by pectinase. This was on par with the wines produced using 1:2 fruit: water ratio, maintaining 24° brix, with nitrogen source and clarified by pectinase (12.31%) or by settling (12.30%). The lowest alcohol content (3.52%) was recorded in the wine produced with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase. The wine prepared with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by settling also had 3.52 per cent alcohol content. This was on par with the wines produced using 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified using settling and wines with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified using pectinase (4.39%). Wines produced using

Table 30. Effect of process parameters on alcohol content of rose apple wines

Alcohol content (%)												
Fruit water ratio (R)	With nitrogen source (N_1)						Without nitrogen source (N_2)					
	Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°B (C_2)		20% sugar (C_3)		Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°B (C_2)		20% sugar (C_3)	
	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2
R_1 (1:1)	3.52	4.39	8.79	11.43	*	*	4.39	3.52	10.55	9.67	*	*
R_2 (1:2)	5.27	5.8	12.31	12.30	*	*	5.62	4.39	13.18	10.55	*	*
R_3 (1:0.07)	7.91	7.91	9.67	10.55	11.43	11.06	8.79	8.79	8.79	11.43	10.55	10.55
Mean R	R_1=7.03				R_2=8.68				R_3=9.78			
Mean C	C_1=5.85				C_2=10.76				C_3=10.89			
Mean N	N_1=8.74						N_2=8.62					
Mean Cl	Cl_1=8.63						Cl_2=8.74					
CD (0.05)	R= 0.75		C= 1.03		N= NS			Cl= NS		R×C×N×Cl = 1.13		

*- contaminated; Cl_1 – Clarification using pectinase; Cl_2 – Clarification by settling

fruit: water ratio of 1:2 and fruit: sugar ratio of 1:1, with nitrogen source and clarified by pectinase (5.27%) or by settling (5.8%) and wines with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by pectinase (5.62%) or by settling (4.39%) were also on par.

Polyphenol content (mgg^{-1})

Polyphenol content of wines was significantly influenced by fruit: water ratio, fruit: sugar ratio and their interaction with nitrogen source and clarification methods (Table 31).

The lowest polyphenol content of wines (73.94mgg^{-1}) was recorded when 1:0.07 fruit: water ratio was used and the highest polyphenol (118.17mgg^{-1}) was recorded in wines produced with 1:1 fruit: water ratio.

Lowest polyphenol content (50.06mgg^{-1}) was observed when fruit: sugar ratio was maintained at 20% sugar and highest polyphenol (116.78mgg^{-1}) was observed in wines prepared with 1:1 fruit: sugar ratio.

Nitrogen source and clarification methods did not significantly influence the polyphenol content of wines.

When the interaction effect was considered, the lowest polyphenol content (36.66mgg^{-1}) was recorded when wine was produced with 1:0.07 fruit: water ratio, 20% sugar, without nitrogen source and clarified using pectinase. This was on par with wine produced in same manner but with nitrogen source and clarified by settling (37.2mgg^{-1}). Polyphenol content was highest (154.12mgg^{-1}) in the wine prepared with 1:1 fruit: water ratio, maintaining 24° brix, with nitrogen source and clarified using pectinase. This was on par with the wine produced in same manner but with fruit: sugar ratio of 1:1 (151.65 mgg^{-1}).

Antioxidant activity (%)

There was significant difference between the antioxidant activity of different rose apple wines prepared with different process parameters (Table 32).

Table 31. Effect of process parameters on polyphenol content of rose apple wines

Polyphenol content (mgg^{-1})												
Fruit water ratio (R)	With nitrogen source (N_1)						Without nitrogen source (N_2)					
	Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°B (C_2)		20% sugar (C_3)		Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°B (C_2)		20% sugar (C_3)	
	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2
R_1 (1:1)	151.65	134.93	154.12	94.52	*	*	115.79	112.34	88.16	93.82	*	*
R_2 (1:2)	137.02	103.91	147.11	64.43	*	*	136.11	108.66	91.7	58.29	*	*
R_3 (1:0.07)	87.84	80.98	85.02	73.29	45.11	37.2	116.38	115.79	87.02	40.7	36.66	81.29
Mean R	R_1=118.17				R_2=105.90				R_3=73.94			
Mean C	C_1=116.78				C_2=89.85				C_3=50.06			
Mean N	N_1=99.79						N_2=91.62					
Mean Cl	Cl_1=105.69						Cl_2=85.72					
CD (0.05)	R= 15.19		C= 2.49		N= NS			Cl= NS		R×C×N×Cl= 3.14		

*- contaminated; Cl_1 – Clarification using pectinase; Cl_2 – Clarification by settling

Table 32. Effect of process parameters on antioxidant activity of rose apple wines

Antioxidant activity (% inhibition)												
Fruit water ratio (R)	With nitrogen source (N_1)						Without nitrogen source (N_2)					
	Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°B (C_2)		20% sugar (C_3)		Fruit: sugar 1:1 (C_1)		Fruit: sugar to maintain 24°B (C_2)		20% sugar (C_3)	
	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2	Cl_1	Cl_2
R_1 (1:1)	80.13	64.88	62.18	83.72	*	*	72.05	75.12	31.66	57.31	*	*
R_2 (1:2)	42.69	72.31	52.82	67.56	*	*	42.56	83.33	45.89	75.26	*	*
R_3 (1:0.07)	37.82	29.10	35.76	28.98	19.49	12.05	73.33	57.44	37.56	15.64	11.03	30.52
Mean R	R_1=65.88				R_2=60.30				R_3=32.39			
Mean C	C_1=60.90				C_2=49.53				C_3=18.27			
Mean N	N_1=49.25						N_2=50.62					
Mean Cl	Cl_1=46.07						Cl_2=53.80					
CD (0.05)	R= 0.62		C= 11.69		N= 0.87			Cl= 0.85		R×C×N×Cl= 0.73		

*- contaminated; Cl_1 – Clarification using pectinase; Cl_2 – Clarification by settling

The highest antioxidant activity (65.88%) was recorded in wines produced with 1:1 fruit: water ratio and the lowest (32.39%) was recorded when 1:0.07 fruit: water ratio was adopted.

Highest antioxidant activity (60.90%) was recorded when fruit: sugar ratio was maintained at 1:1 and the lowest (18.27%) was recorded when 20% sugar was adopted.

Significantly higher antioxidant activity was recorded (50.62%) when wine was prepared without nitrogen source compared to wines produced with nitrogen source (49.25%).

Higher antioxidant activity (53.80%) was recorded in wines clarified by settling compared to wines clarified using pectinase (46.07%).

When the interaction effect was considered, the highest antioxidant activity (83.72%) was recorded in the wine prepared with 1:1 fruit: water ratio, maintaining 24° brix, with nitrogen source and clarified by settling. This wine was on par with the wine produced using 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by settling (83.33%). The lowest antioxidant activity (11.03%) was recorded in the wine produced using 1:0.07 fruit: water ratio, 20% sugar, without nitrogen source and clarified using pectinase.

4.2.3.3. Sensory quality

Sensory quality parameters of wines were recorded after completion of secondary fermentation. There was significant difference in the sensory quality parameters of rose apple wines except for aroma (Table 33).

Appearance

Mean score for appearance varied between 1.8 to 2.9. The maximum mean score for appearance (2.9) was recorded in the rose apple wine produced using 1:0.07 fruit: water ratio, maintaining 24° brix, with nitrogen source and clarified by pectinase which was closely followed by the wine prepared with fruit: water ratio of 1:2, fruit: sugar ratio of 1:1, without addition of nitrogen source and clarified by pectinase (2.8).

The minimum mean score (1.8) was obtained for the wines prepared with 1:0.07 fruit: water ratio, maintaining 24° brix, with or without nitrogen source and clarified by settling.

Aroma

Process parameters did not significantly influence the aroma of different wines. However, the mean score for aroma ranged from 3.4 to 4.7.

Taste/Texture

Mean score for taste/texture of different wines varied from 3.2 to 5.2. The maximum mean score for taste/texture (5.2) was recorded in the wine produced using 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, without addition of nitrogen source and clarified by settling. The same score was observed for the wine produced with 1:2 fruit: water, 1:1 fruit: sugar ratio, without nitrogen source and clarified by settling. This was followed by the wine produced using 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase (5.0). The minimum mean score for taste/texture (3.2) was obtained for the wine produced with 1:1 fruit: water ratio, maintaining 24° brix, without addition of nitrogen source and clarified by pectinase and for wine produced with 1:0.07 fruit: water ratio, maintaining 24° brix, with nitrogen source and clarified by settling.

After taste

Mean score for after taste of rose apple wines ranged between 1.5 to 2.5. The wine produced using 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, without addition of nitrogen source and clarified by settling had the maximum mean score for after taste (2.5). Wine which was produced with 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, without addition of nitrogen source and clarified by settling also had mean score of 2.5. This was followed by the wine prepared with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified using pectinase (2.4). The wines prepared with 1:0.07 fruit: water ratio, 20% sugar and without addition of nitrogen source had the minimum mean score 1.5 with irrespective of clarification methods.

Table 33. Effect of process parameters on sensory quality of rose apple wines

Treatments	Appearance		Aroma		Taste/Texture		After taste		Overall impression	
	Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank
T_1 –1:1 F-W+1:1 F-S+N_1+Cl_1	2.1	110.00	4.4	145.00	5.0	210.20	2.4	203.00	1.7	201.00
T_2–1:1 F-W+1:1 F-S+N_1+Cl_2	1.9	98.90	4.5	157.25	4.6	177.40	2.3	176.95	1.7	194.90
T_3 –1:1 F-W+1:1 F-S+N_2+Cl_1	2.2	122.60	4.4	151.55	4.9	203.70	2.2	176.55	1.6	167.20
T_4 –1:1 F-W+1:1 F-S+N_2+Cl_2	2.2	125.60	4.6	162.80	5.2	225.40	2.5	206.25	1.7	201.20
T_5 –1:1 F-W+24°Brix+N_1+Cl_1	2.3	138.70	3.9	119.10	3.7	122.90	1.7	113.90	1.2	109.40
T_6 –1:1 F-W+24°Brix+N_1+Cl_2	2.1	101.15	4.0	115.10	3.6	115.20	1.8	115.25	1.2	104.90
T_7 –1:1 F-W+24°Brix+N_2+Cl_1	2.5	173.25	3.4	86.40	3.2	89.55	1.6	101.90	1.3	112.85
T_8 –1:1 F-W+24°Brix+N_2+Cl_2	2.2	127.35	3.6	93.75	3.3	92.50	1.6	103.15	1.3	123.90
T_9 –1:2 F-W+1:1 F-S+N_1+Cl_1	2.6	179.55	3.9	102.55	4.3	160.35	2.0	157.65	1.5	155.65
T_{10} –1:2 F-W+1:1 F-S+N_1+Cl_2	2.1	111.25	4.2	128.15	3.8	122.85	2.3	183.15	1.3	125.90
T_{11} –1:2 F-W+1:1 F-S+N_2+Cl_1	2.8	208.75	4.1	123.75	3.6	110.45	1.8	123.05	1.2	105.10
T_{12} –1:2 F-W+1:1 F-S+N_2+Cl_2	2.0	107.70	4.6	159.70	5.2	222.90	2.5	208.40	1.7	196.95
T_{13} –1:2 F-W+24°Brix+N_1+Cl_1	2.5	167.40	4.1	135.85	3.3	96.85	1.9	135.80	1.3	122.95
T_{14} –1:2 F-W+24°Brix+N_1+Cl_2	2.5	168.75	4.5	164.30	3.5	103.45	1.9	140.05	1.5	154.15
T_{15} –1:2 F-W+24°Brix+N_2+Cl_1	2.7	196.30	4.5	157.60	4.2	157.75	1.7	122.14	1.3	114.00
T_{16} –1:2 F-W+24°Brix+N_2+Cl_2	2.4	155.40	4.5	152.70	4.2	156.55	1.7	116.85	1.4	132.95
T_{17} –1:0.07 F-W+1:1 F-S+N_1+Cl_1	1.9	104.45	4.5	155.90	4.5	174.30	2.2	171.35	1.6	177.95
T_{18} –1:0.07 F-W+1:1 F-S+N_1+Cl_2	2.4	165.20	4.0	124.25	3.9	125.50	2.1	159.90	1.5	157.80
T_{19} –1:0.07 F-W+1:1 F-S+N_2+Cl_1	2.1	115.75	4.7	172.40	4.6	177.40	2.1	159.15	1.4	138.05
T_{20} –1:0.07 F-W+1:1 F-S+N_2+Cl_2	1.9	78.10	4.5	154.05	4.3	164.10	2.1	155.15	1.4	143.15
T_{21} –1:0.07 F-W+24°Brix+N_1+Cl_1	2.9	229.75	4.3	146.35	3.5	114.80	1.7	108.40	1.3	125.85
T_{22} –1:0.07 F-W+24°Brix+N_1+Cl_2	1.8	75.20	4.3	146.15	3.2	96.40	1.6	140.81	1.2	120.15
T_{23} –1:0.07 F-W+24°Brix+N_2+Cl_1	2.7	200.10	4.4	157.35	3.8	132.20	1.9	143.00	1.4	140.80
T_{24} –1:0.07 F-W+24°Brix+N_2+Cl_2	1.8	85.40	4.7	170.05	4.0	140.95	1.9	128.20	1.4	139.10
T_{25} –1:0.07 F-W+20% Sugar+N_1+Cl_1	2.7	204.65	4.5	153.50	3.7	118.40	1.8	130.70	1.4	131.95
T_{26} –1:0.07 F-W+20% Sugar+N_1+Cl_2	1.9	86.15	4.2	136.70	3.5	105.05	1.6	97.10	1.3	112.90
T_{27} –1:0.07 F-W+20% Sugar+N_2+Cl_1	2.7	199.65	4.1	127.30	3.5	107.10	1.5	93.85	1.3	123.70
T_{28} –1:0.07 F-W+20% Sugar+N_2+Cl_2	1.9	97.10	4.2	134.45	3.6	109.80	1.5	92.35	1.3	110.60
K value	92.96		21.57		69.97		51.27		42.18	
χ^2	40.113									

F-W – Fruit: water ratio; F-S – Fruit: sugar ratio; N_1 – With nitrogen source; N_2 – Without nitrogen source; Cl_1 – Clarified by pectinase; Cl_2 – Clarified by settling

Ov*erall impression*

Mean score for overall impression of rose apple wines varied from 1.2 to 1.7. The maximum mean score for overall impression (1.7) was obtained for the wines prepared with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio and with nitrogen source irrespective of clarification methods. The same score was obtained for the wines prepared using fruit: water ratio of 1:1 or 1:2, fruit: sugar ratio of 1:1, without addition of nitrogen source and clarified by settling. This was closely followed by the wine prepared with fruit: water ratio of 1:1, fruit: sugar ratio 1:1, without addition of nitrogen source and clarified using pectinase (1.6). The wine prepared with 1:0.07 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase also had mean score of 1.6. The minimum mean score for overall impression (1.2) was obtained for the wines prepared using 1:1 fruit: water ratio, maintaining 24° brix and with nitrogen source irrespective of clarification methods. Wines prepared with 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, without addition of nitrogen source and clarified using pectinase and with 1:0.07 fruit: water ratio, maintaining 24° brix, with nitrogen source and clarified by settling also had mean score of 1.2.

4.3. SELECTION OF THE SUPERIOR FRUIT WINES

Wines having high yield, superior antioxidant activity with alcohol content with in the approved range of low alcoholic beverages accepted by Kerala State Government (not more than 7%) and with good sensory quality parameters were considered for selecting the three superior wines. As none of the wines had all the superior sensory quality parameters, total sensory score was computed and considered for selection of superior wines.

Table 34. Total sensory score of fruit wines

	Total sensory score					
	Jamun		Papaya		Rose apple	
Treatments	Mean score	Rank	Mean score	Rank	Mean score	Rank
T_1–1:1 F-W+1:1 F-S+N_1+Cl_1	18	218.10	17	232.64	15.5	195.60
T_2–1:1 F-W+1:1 F-S+N_1+Cl_2	16.5	188.45	15	186.15	15	170.40
T_3–1:1 F-W+1:1 F-S+N_2+Cl_1	18.5	230.80	15	183.40	15.5	180.90
T_4–1:1 F-W+1:1 F-S+N_2+Cl_2	16	182.10	14.5	176.90	16	204.20
T_5–1:1 F-W+24°Brix+N_1+Cl_1	11	70.85	10	73.00	12.5	113.10
T_6–1:1 F-W+24°Brix+N_1+Cl_2	11.5	79.15	8.5	39.05	12.5	102.15
T_7–1:1 F-W+24°Brix+N_2+Cl_1	11.5	84.00	9.5	55.25	12	88.40
T_8–1:1 F-W+24°Brix+N_2+Cl_2	11.5	85.15	8	29.40	12	88.60
T_9–1:2 F-W+1:1 F-S+N_1+Cl_1	18	213.15	15.5	201.80	14.5	152.95
T_{10}–1:2 F-W+1:1 F-S+N_1+Cl_2	13	119.75	12.5	136.65	13.5	131.30
T_{11}–1:2 F-W+1:1 F-S+N_2+Cl_1	16	181.70	14.5	170.85	13.5	129.70
T_{12}–1:2 F-W+1:1 F-S+N_2+Cl_2	16	180.15	12	120.05	16	196.40
T_{13}–1:2 F-W+24°Brix+N_1+Cl_1	14	139.05	13	139.40	14	121.20
T_{14}–1:2 F-W+24°Brix+N_1+Cl_2	13	111.65	14.5	171.20	14	139.35
T_{15}–1:2 F-W+24°Brix+N_2+Cl_1	14	136.85	13	140.60	14.5	156.75
T_{16}–1:2 F-W+24°Brix+N_2+Cl_2	12	90.30	13.5	150.45	14	152.20
T_{17}–1:0.07 F-W+1:1 F-S+N_1+Cl_1	16	170.95	14	170.45	15	166.80
T_{18}–1:0.07 F-W+1:1 F-S+N_1+Cl_2	14.5	143.20	14	160.65	14	144.10
T_{19}–1:0.07 F-W+1:1 F-S+N_2+Cl_1	15	157.30	14	164.80	15	168.90
T_{20}–1:0.07 F-W+1:1 F-S+N_2+Cl_2	14	136.35	13.5	147.90	14.5	151.35
T_{21}–1:0.07 F-W+24°Brix+N_1+Cl_1	*	*	12.5	118.25	14	137.35
T_{22}–1:0.07 F-W+24°Brix+N_1+Cl_2	*	*	11	118.45	12	98.55
T_{23}–1:0.07 F-W+24°Brix+N_2+Cl_1	11	70.85	13	132.30	14	155.10
T_{24}–1:0.07 F-W+24°Brix+N_2+Cl_2	11.5	79.15	13	133.95	13.5	129.15
T_{25}–1:0.07 F-W+20% Sugar+N_1+Cl_1	11.5	84.00	13	132.40	14	142.85
T_{26}–1:0.07 F-W+20% Sugar+N_1+Cl_2	11.5	85.15	13.5	141.25	12.5	98.60
T_{27}–1:0.07 F-W+20% Sugar+N_2+Cl_1	11	70.85	13.5	149.55	13	117.90
T_{28}–1:0.07 F-W+20% Sugar+N_2+Cl_2	11.5	84.00	14	162.10	12.5	100.15
K value	119.21		89.49		44.61	
χ^2	37.652		40.113			

*- contaminated; F-W – Fruit: water ratio; F-S – Fruit: sugar ratio; N_1 – With nitrogen source; N_2 – Without nitrogen source; Cl_1 – Clarified by pectinase; Cl_2 – Clarified by settling

The mean total sensory score of jamun wines varied from 11 to 18.5. The wine produced using 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by pectinase had the highest mean total score (18.5). This was followed by the wines produced using 1:1 or 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase (18). The wine prepared with 1:1 fruit: water ratio, maintaining 24° brix, with nitrogen source and clarified using pectinase had the lowest mean total score (11). The same score was obtained for the wines produced with 1:0.07 fruit: water ratio, maintaining 24° brix or 20% sugar, without nitrogen source and clarified using pectinase.

Mean total sensory score of papaya wines ranged between 8 to 17. The highest mean total score (17) was obtained for the wine produced using 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase. This was followed by the wine produced using 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase (15.5). Wine produced using 1:1 fruit: water ratio, maintaining 24° brix, without nitrogen source and clarified by settling had the lowest mean total score (8).

Mean total sensory score of rose apple wines ranged between 12 to 16. The wines produced using 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, without addition of nitrogen source and clarified by settling had the maximum mean total score (16). Wine which was produced with 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, without addition of nitrogen source and clarified by settling also had mean score of 16. This was followed by the wines prepared with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, and clarified using pectinase irrespective of nitrogen source (15.5). The wines prepared with 1:1 fruit: water ratio, maintaining 24° brix and without addition of nitrogen source irrespective of clarification methods had the minimum mean total score (12). The same score was obtained for the wine prepared with 1:0.07 fruit: water ratio, maintaining 24° brix, with nitrogen source and clarified by settling.

4.3.1. Jamun

The following jamun wines were selected initially (Table 35).

Table 35. Wines with superior quality parameters

Wines with varying process parameters	Yield (%)	Antioxidant activity (% inhibition)	Alcohol content (%)	Sensory quality parameters	
				Individual scores	Total sensory score
1:1 F-W+1:1 F-S+ N_1+Cl_1 (T_1)	95.4	92.5	3.52	Highest appearance score (3.0)	18
				Highest after taste score (2.7)	
1:1 F-W+1:1 F-S+ N_1+Cl_2 (T_2)	91.9	89.7	5.86	Low appearance score (1.9)	16.5
				High after taste score (2.5)	
1:1 F-W+1:1 F-S+ N_2+Cl_1 (T_3)	92.9	93.03	3.52	Highest overall impression score (2.0)	18.5
				Highest taste/texture score (5.4)	
1:1 F-W+1:1 F-S+ N_2+Cl_2 (T_4)	89.2	65.69	4.39	Least appearance score (1.5)	16
				High aroma score (5.4)	
1:2 F-W+1:1 F-S+ N_1+Cl_1 (T_9)	92.8	95.64	5.86	Highest appearance score (3.0)	18
1:2 F-W+1:1 F-S+ N_1+Cl_2 (T_{10})	85.9	78.86	6.59	Low appearance score (1.8)	13
1:2 F-W+1:1 F-S+ N_2 +Cl_1 (T_{11})	85.7	93.36	4.32	High taste/texture score (5.2)	16
1:2 F-W+1:1 F-S+ N_2+Cl_2 (T_{12})	89.6	86.23	5.86	Low appearance score (1.9)	16

F-W – Fruit: water ratio; F-S – Fruit: sugar ratio; N_1 – With nitrogen source; N_2 – Without nitrogen source; Cl_1 – Clarified by pectinase; Cl_2 – Clarified by settling

4.3.2. Papaya

The following papaya wines were selected initially (Table 36).

Table 36. Wines with superior quality parameters.

Wines with varying process parameters	Yield (%)	Antioxidant activity (% inhibition)	Alcohol content (%)	Sensory quality parameters	
				Individual scores	Total sensory score
1:1 F-W+1:1 F-S+ N_1+Cl_1 (T_1)	84	86.54	3.52	Highest overall impression score (2.0) Highest taste/texture score (5.0)	17
1:1 F-W+1:1 F-S+ N_1+Cl_2 (T_2)	87	86.93	4.39	High taste/texture score (4.6)	15
1:2 F-W+1:1 F-S+ N_1+Cl_1 (T_9)	90.7	82.95	5.13	Highest appearance score (2.9)	15.5
1:2 F-W+1:1 F-S+ N_1+Cl_2 (T_{10})	87.3	82.69	5.27	Good appearance score (2.1)	12.5
1:2 F-W+1:1 F-S+ N_2+ Cl_1 (T_{11})	74.7	63.2	4.65	Low overall impression score (1.3)	14.5
1:2 F-W+1:1 F-S+ N_2+ Cl_2 (T_{12})	86	82.82	5.13	Low appearance score (1.9)	12

F-W – Fruit: water ratio; F-S – Fruit: sugar ratio; N_1 – With nitrogen source; N_2 – Without nitrogen source; Cl_1 – Clarified by pectinase; Cl_2 – Clarified by settling

4.3.3. Rose apple

The following rose apple wines were selected initially (Table 37).

Table 37. Wines with superior quality parameters.

Wines with varying process parameters	Yield (%)	Antioxidant activity (% inhibition)	Alcohol content (%)	Sensory quality parameters	
				Individual scores	Total sensory score
1:1 F-W+1:1 F-S+ N_1+Cl_1 (T_1)	91.33	80.13	3.52	Highest overall impression score (1.7)	15.5
1:1 F-W+1:1 F-S+ N_1+Cl_2 (T_2)	86.33	64.88	4.39	Low appearance score (1.9) Highest overall impression score (1.7)	15
1:1 F-W+1:1 F-S+ N_2+Cl_1 (T_3)	83	72.05	4.39	High overall impression score (1.6)	15.5
1:1 F-W+1:1 F-S+ N_2+Cl_2 (T_4)	92.33	75.12	3.52	Highest taste/texture score (5.2)	16
1:2 F-W+1:1 F-S+ N_1+Cl_2 (T_{10})	93.33	72.31	5.8	Low overall impression score (1.3)	13.5
1:2 F-W+1:1 F-S+ N_2+Cl_1 (T_{11})	83.67	42.56	5.62	High appearance score (2.8) Least overall impression score (1.2)	13.5
1:2 F-W+1:1 F-S+ N_2+ Cl_2 (T_{12})	93.33	83.33	4.39	Highest taste/texture score (5.2) Highest overall impression score (1.7)	16

F-W – Fruit: water ratio; F-S – Fruit: sugar ratio; N_1 – With nitrogen source; N_2 – Without nitrogen source; Cl_1 – Clarified by pectinase; Cl_2 – Clarified by settling

Thus the following three wines with superior antioxidant activity, yield and total sensory score confirming to the standard of low alcoholic beverage were selected for further storage studies.

Jamun

1. Wines prepared with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase (T_1)
2. Wines prepared with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by pectinase (T_3)
3. Wines prepared with 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase (T_9)

Papaya

1. Wines prepared with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase (T_1)
2. Wines prepared with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by settling (T_2)
3. Wines prepared with 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase (T_9)

Rose apple

1. Wines prepared with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase (T_1)
2. Wines prepared with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by settling (T_4)
3. Wines prepared with 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by settling (T_{12})

4.4 STORAGE STABILITY OF SELECTED FRUIT WINES

4.4.1. Jamun

The three superior jamun wines selected based on the yield, antioxidant activity, alcohol content and sensory quality parameters were stored in amber coloured glass bottles under ambient condition for a period of two months for analysing the storage stability.

4.4.1.1. Chemical quality

Polyphenol and alcohol content of the selected three superior jamun wines were analysed initially at the time of storage and after two months of storage.

Polyphenol content (mgg^{-1})

The polyphenol content of the stored wines was significantly influenced by treatments, storage period and their interactions (Table 38).

Polyphenol content was decreased during storage from 189.18mgg^{-1} at the time of storage to 183.89mgg^{-1} at two months after storage.

The polyphenol content of wine prepared with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified using pectinase was decreased from 188.28mgg^{-1} at the time of storage to 182.93mgg^{-1} after two months of storage. The wine produced using 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by pectinase had a polyphenol content of 253.29mgg^{-1} at the time of storage and was decreased to 247.65mgg^{-1} at two months of storage. Polyphenol content of wine prepared using 1:2 fruit: water ratio, 1:1 fruit: sugar, with nitrogen source and clarified by pectinase was decreased from 125.92mgg^{-1} at the time of storage to 121.11mgg^{-1} after two months of storage.

Among the treatments, the lowest mean polyphenol content (123.51mgg^{-1}) after storage was obtained for the wine produced with 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified using pectinase and the highest mean

($250.47 mgg^{-1}$) content was obtained for the wine prepared with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by pectinase.

Alcohol content (%)

The alcohol content of the stored wines was significantly influenced by treatments, storage period and their interactions (Table 38).

Alcohol content was decreased during storage from 4.3 per cent at the time of storage to 3.75 per cent at two months after storage.

The alcohol content of wine prepared with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified using pectinase was decreased from 3.52 per cent at the time of storage to 3.16 per cent after two months of storage. The wine produced using 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by pectinase had an alcohol content of 3.52 per cent at the time of storage and was decreased to 2.81 per cent at two months of storage. Alcohol content of wine prepared using 1:2 fruit: water ratio, 1:1 fruit: sugar, with nitrogen source and clarified by pectinase was decreased from 5.86 per cent at the time of storage to 5.27 per cent after two months of storage.

Among the treatments, the highest mean alcohol content (5.56%) after storage was recorded in the wine produced using fruit: water ratio of 1:2, fruit: sugar ratio of 1:1, with nitrogen source and clarified using pectinase and the lowest mean (3.16%) content was obtained for the wine prepared with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by pectinase.

4.4.1.2. Microbial load

The microbial load of three superior wines were analysed initially and after two months of storage (Table 39). Spread plate method without dilution was used for determining the colony-forming units of bacterial and fungal population.

The bacterial load in all the wines were too few to count (TFTC) at the time of storage.

Table.38. Effect of storage on polyphenol and alcohol content of jamun wines

Treatments (T)	Polyphenol content (mgg^{-1})			Alcohol content (%)		
	Months of storage (S)		Mean T	Months of storage (S)		Mean T
	0	2		0	2	
1:1 F-W+1:1 F-S +N_1+Cl_1 (T_1)	188.28	182.93	185.60	3.52	3.16	3.34
1:1 F-W+1:1 F-S +N_2+Cl_1 (T_3)	253.29	247.65	250.47	3.52	2.81	3.16
1:2 F-W+1:1 F-S +N_1+Cl_1 (T_9)	125.92	121.11	123.51	5.86	5.27	5.56
Mean S	189.18	183.89		4.3	3.75	
CD (0.05)	T= 0.16	S= 0.11	T×S= 0.21	T= 0.24	S= 0.20	T×S= 0.27

F-W – Fruit: water ratio; F-S – Fruit: sugar ratio; N_1 – With nitrogen source;
N_2 – Without nitrogen source; Cl_1 – Clarified by pectinase

Table 39. Effect of storage on microbial load in jamun wines

Treatments (T)	Microbial load (colony forming units/ml)			
	Bacteria (cfu/ml)		Fungi (cfu/ml)	
	Months of storage (S)			
	0	2	0	2
1:1 F-W+1:1 F-S+N_1+Cl_1 (T1)	TFTC	11	TFTC	7
1:1 F-W+1:1 F-S+N_2+Cl_1 (T_3)		15		9
1:2 F-W+1:1 F-S+N_1+Cl_1 (T_9)		19		8
CD (0.05)		2.20		NS

F-W – Fruit: water ratio; F-S – Fruit: sugar ratio; N_1 – With nitrogen source;
N_2 – Without nitrogen source; Cl_1 – Clarified by pectinase;
TFTC – Too few to count

Minimum bacterial count (11 cfu/ml) was obtained for the wine prepared with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified using pectinase after two months of storage. Maximum bacterial count (19 cfu/ml) was obtained for the wine produced using 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase.

The fungal load in all the wines were too few to count (TFTC) at the time of storage.

There was no significant difference between the fungal count at two months of storage. However, minimum fungal count (7 cfu/ml) was recorded in the wine prepared with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified using pectinase. Maximum fungal count (9 cfu/ml) was obtained for the wine produced using 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by pectinase.

4.4.2. Papaya

The three superior papaya wines selected based on the yield, antioxidant activity, alcohol content and sensory quality parameters were stored in amber coloured glass bottles under ambient condition for a period of two months for analysing the storage stability.

4.4.2.1. Chemical quality

Polyphenol and alcohol content of three superior papaya wines were analysed initially at the time of storage and after two months of storage.

Polyphenol content (mgg^{-1})

The polyphenol content of the stored wines was significantly influenced by treatments, storage period and their interactions (Table 40).

Polyphenol content was decreased during storage from 63.46mgg^{-1} at the time of storage to 60.13mgg^{-1} at two months after storage.

The polyphenol content of wine produced using 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified using pectinase was decreased from 83.65mgg^{-1} at the time of storage to 78.93mgg^{-1} after two months of storage. Polyphenol content of wine prepared with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by settling was decreased from 50.19mgg^{-1} at the time of storage to 48.17mgg^{-1} after two months of storage. The wine prepared with 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase had a polyphenol content of 56.55mgg^{-1} at the time of storage and was decreased to 53.29mgg^{-1} at two months of storage.

Among the treatments, the lowest mean polyphenol content (49.18mgg^{-1}) after storage was recorded in the wine produced with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified using settling and the highest mean (81.3mgg^{-1}) content was obtained for the wine prepared with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified using pectinase.

Alcohol content (%)

The alcohol content of the stored wines was significantly influenced by treatments, storage period and their interactions (Table 40).

Alcohol content was increased during storage from 4.81 per cent at the time of storage to 5.13 per cent at two months after storage.

The alcohol content of wine produced using 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified using pectinase was increased from 3.52 per cent at the time of storage to 4.39 per cent after two months of storage. The wine prepared with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by settling had an alcohol content of 4.39 per cent at the time of storage and was enhanced to 5.13 per cent at two months of storage. Alcohol content of wine prepared using 1:2 fruit: water ratio, 1:1 fruit: sugar ratio with nitrogen source and clarified by pectinase was increased from 5.13 per cent at the time of storage to 5.86 per cent after two months of storage.

Among the treatments, the highest mean alcohol content (5.49%) after storage was obtained for the wine produced using 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified using pectinase and the lowest mean (3.95%) was obtained for the wine prepared with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase.

4.4.2.2. Microbial load

The microbial load of three superior wines were analysed initially and after two months of storage (Table 41).

The bacterial load in all the wines were too few to count (TFTC) at the time of storage.

Minimum bacterial count (5 cfu/ml) was recorded in the wine prepared with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by settling after two months of storage. Maximum bacterial count (18 cfu/ml) was recorded in the wine produced with 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase.

The fungal load in all the wines were too few to count (TFTC) at the time of storage.

After two months of storage, minimum fungal count (2 cfu/ml) was recorded in the wine prepared using 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by settling. Maximum fungal count (14 cfu/ml) was recorded in the wine produced using 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase.

4.4.3. Rose apple

The three superior rose apple wines selected based on the yield, antioxidant activity, alcohol content and sensory quality parameters were stored in amber coloured glass bottles under ambient condition for a period of two months for analysing the storage stability.

Table.40. Effect of storage on polyphenol and alcohol content of papaya wines

Treatments (T)	Polyphenol content (mgg^{-1})			Alcohol content (%)		
	Months of storage (S)		Mean T	Months of storage (S)		Mean T
	0	2		0	2	
1:1 F-W+1:1 F-S+ N_1+Cl_1 (T_1)	83.65	78.93	81.3	3.52	4.39	3.95
1:1 F-W+1:1 F-S+ N_1+Cl_2 (T_2)	50.19	48.17	49.18	4.39	5.13	4.76
1:2 F-W+1:1 F-S+ N_1+Cl_1 (T_9)	56.55	53.29	54.92	5.13	5.86	5.49
Mean S	63.46	60.13		4.81	5.13	
CD (0.05)	T= 0.18	S= 0.20	T×S= 0.29	T= 0.19	S= 0.16	T×S= 0.29

F-W – Fruit: water ratio; F-S – Fruit: sugar ratio; N_1 – With nitrogen source;

Cl_1 – Clarified by pectinase; Cl_2 – Clarified by settling

Table 41. Effect of storage on microbial load in papaya wines

Treatments (T)	Microbial load (colony forming units/ml)			
	Bacteria (cfu/ml)		Fungi (cfu/ml)	
	Months of storage (S)			
	0	2	0	2
1:1 F-W+1:1 F-S+ N_1+Cl_1 (T_1)	TFTC	8	TFTC	7
1:1 F-W+1:1 F-S+ N_1+Cl_2 (T_2)		5		2
1:2 F-W+1:1 F-S+ N_1+Cl_1 (T_9)		18		14
CD (0.05)		2.2		2.2

F-W – Fruit: water ratio; F-S – Fruit: sugar ratio; N_1 – With nitrogen source

Cl_1 – Clarified by pectinase; Cl_2 – Clarified by settling; TFTC – Too few to count

4.4.3.1. Chemical quality

Polyphenol and alcohol content of three superior papaya wines were analysed initially at the time of storage and after two months of storage.

Polyphenol content (mgg^{-1})

The polyphenol content of the stored wines was significantly influenced by treatments, storage period and their interactions (Table 42).

Polyphenol content was decreased during storage from 124.22mgg^{-1} at the time of storage to 120.26mgg^{-1} at two months after storage.

The polyphenol content of wine prepared with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified using pectinase was decreased from 151.65mgg^{-1} at the time of storage to 148.38mgg^{-1} after two months of storage. The wine produced using 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by settling had a polyphenol content of 112.34mgg^{-1} at the time of storage and was decreased to 109.47mgg^{-1} at two months of storage. Polyphenol content of wine prepared using 1:2 fruit: water ratio, 1:1 fruit: sugar, without nitrogen source and clarified by settling was decreased from 108.66mgg^{-1} at the time of storage to 102.93mgg^{-1} after two months of storage.

Among the treatments, the lowest mean polyphenol content (105.79mgg^{-1}) after storage was recorded in the wine produced with 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by settling. The highest mean (150.01mgg^{-1}) was recorded in the wine prepared with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified using pectinase.

Alcohol content (%)

The alcohol content of the stored wines was significantly influenced by treatments, storage period and their interactions (Table 42).

Alcohol content was enhanced during storage from 3.81 per cent at the time of storage to 4.45 per cent at two months after storage.

The alcohol content of wine prepared with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified using pectinase was enhanced from 3.52 per cent at the time of storage to 3.87 per cent after two months of storage. The wine produced using 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by settling had an alcohol content of 3.52 per cent at the time of storage and was increased to 4.22 per cent at two months of storage. Alcohol content of wine prepared using 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by settling was enhanced from 4.39 per cent at the time of storage to 5.27 per cent after two months of storage.

Among the treatments, the highest mean alcohol content (4.83%) after storage was recorded in the wine produced using 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by settling. The lowest mean (3.69%) was recorded in the wine prepared with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase.

4.4.3.2. Microbial load

The microbial load of three superior wines were analysed initially and after two months of storage (Table 43).

The bacterial load in all the wines were too few to count (TFTC) at the time of storage.

Minimum bacterial count (3 cfu/ml) was noticed in the wine prepared with 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by settling after two months of storage. Maximum bacterial count (13 cfu/ml) was noticed in the wine produced with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by settling.

The fungal load in all the wines were too few to count (TFTC) at the time of storage.

There was no significant difference between the fungal count after two months of storage. However, minimum fungal count (4 cfu/ml) was noticed in the wine prepared with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified using pectinase. The wine prepared with 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by settling also had 4 cfu/ml fungal count. Maximum fungal count (6 cfu/ml) was noticed in the wine produced with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by settling.

Table 42. Effect of storage on polyphenol and alcohol content of rose apple wines

Treatments (T)	Polyphenol content (mgg^{-1})			Alcohol content (%)		
	Months of storage (S)		Mean T	Months of storage (S)		Mean T
	0	2		0	2	
1:1 F-W+1:1 F-S+ N_1+Cl_1 (T_1)	151.65	148.38	150.01	3.52	3.87	3.69
1:1 F-W+1:1 F-S+ N_2+Cl_2 (T_4)	112.34	109.47	110.9	3.52	4.22	3.87
1:2 F-W+1:1 F-S+ N_2+ Cl_2 (T_{12})	108.66	102.93	105.79	4.39	5.27	4.83
Mean S	124.22	120.26		3.81	4.45	
CD (0.05)	T= 0.18	S= 0.14	T×S= 0.20	T= 0.26	S= 0.16	T×S= 0.29

F-W – Fruit: water ratio; F-S – Fruit: sugar ratio; N_1 – With nitrogen source

N_2 – Without nitrogen source; Cl_1 – Clarified by pectinase; Cl_2 – Clarified by settling

Table 43. Effect of storage on microbial load in rose apple wines

Treatments (T)	Microbial load (colony forming units/ml)			
	Bacteria (cfu/ml)		Fungi (cfu/ml)	
	Months of storage (S)			
	0	2	0	2
1:1 F-W+1:1 F-S+ N_1+Cl_1 (T_1)	TFTC	5	TFTC	4
1:1 F-W+1:1 F-S+ N_2+Cl_2 (T_4)		13		6
1:2 F-W+1:1 F-S+ N_2+ Cl_2 (T_{12})		3		4
CD (0.05)		2.20		NS

F-W – Fruit: water ratio; F-S – Fruit: sugar ratio; N_1 – With nitrogen source

N_2 – Without nitrogen source; Cl_1 – Clarified by pectinase; Cl_2 – Clarified by settling;

TFTC – Too few to count

Discussion

5. DISCUSSION

Consumers today are becoming increasingly conscious of the health, safety and nutritional aspects of their food. The tendency is to minimise contamination from chemicals and synthetic foods and choose therapy and nutrition through natural resources. A paradigm shift can be seen towards the utilization of minor or underutilized or neglected fruit in Kerala, which are considered to have an important role in mitigating malnutrition and poverty in developing and under developed countries, due to their vitamins, antioxidants, organic acids and phenolic contents. A number of acceptable value added products can be prepared from under exploited fruits retaining their nutritional and medicinal properties.

Fruit wines are fermented alcoholic beverages produced from a variety of base ingredients and can be made from virtually any plant matter that can be fermented. Fruit wines are wines produced from the fruits other than grapes. Wine can be made from any fruit having sufficient fermentable sugar, nitrogen source and other requirements for yeast growth.

Fruit wines were prepared from three underexploited fruits viz., jamun, papaya and rose apple independently by varying the process parameters viz., fruit: water ratio, fruit: sugar ratio, nitrogen source and clarification methods. Fruit: water ratio was tried at 1:1, 1:2 and 1.0.07; fruit: sugar ratio was at 1:1, for maintaining 24° brix and 20% sugar, with or without nitrogen source, thus forming 18 different wines under each fruit. The resultant 18 different fruit wines after primary fermentation were analysed for physical quality parameters and subjected to clarification by pectinase enzyme and by settling, thus forming 36 different wines under each fruit.

The results obtained from the study on “Technology refinement for wine production from under exploited fruits” are discussed in this chapter under the following headings.

1. Quality analysis of fruit wines
2. Selection of the superior fruit wines

3. Storage stability of selected fruit wines

5.1. QUALITY ANALYSIS OF FRUIT WINES

The wines produced by varying process parameters were subjected to quality analysis independently. Jamun (*Syzygium cumini*) commonly known as black plum, evergreen indigenous minor fruit crop of the tropics is gaining popularity among the consumers due to its balanced sugar, acid, antioxidant property and tannin content (Das, 2009). It is normally consumed fresh and is known to have nutraceutical and therapeutic values (Khurdiya and Roy, 1985). The wines that were prepared from jamun had an attractive dark purple colour (Plate 3). Papaya (*Carica papaya*) is a tropical fruit rich in vitamins, phytonutrients, and minerals. It has sweet taste, vibrant colour and provided with wide health benefits (Cholassery *et al*., 2019). Papaya wines were light yellowish colour with flavour of papaya fruit (Plate 4). Umeh *et al*., (2015) reported that papaya wine prepared had a brilliant yellow colour and a slight sweet flavour. Rose apple (*Syzygium jambos*) is the fruit of tropics, with a very mild and slightly sweet taste similar to apples, crisp watery texture with > 93% moisture content. The wines prepared from rose apple were creamy white colour (Plate 5). There was significant difference in quality parameters of wine in terms of fruit: water ratios, fruit: sugar ratios, use of nitrogen source and clarification method.

The rate of fermentation of the jamun wines ranged from 0.013°Brix to 0.056°Brix/24 hours. In papaya wines, fermentation rate varied between 0.012°Brix to 0.051°Brix/24 hours and 0.013°Brix to 0.039°Brix/24 hours in rose apple wines. Wines produced using 1:2 fruit: water ratio had highest fermentation rate in jamun, papaya and rose apple wines. Joshi *et al*. (2012b) reported that the rate of fermentation increased with increase in dilution level due to the better fermentation conditions provided by the dilution of thick jamun pulp. Wines prepared by addition of nitrogen source had highest rate of fermentation in papaya and rose apple wines. This was in line with the findings of Joshi *et al*. (1990) who had reported that addition of DAHP (0.1%) enhanced the rate of fermentation in wild apricot wine irrespective of dilution levels.

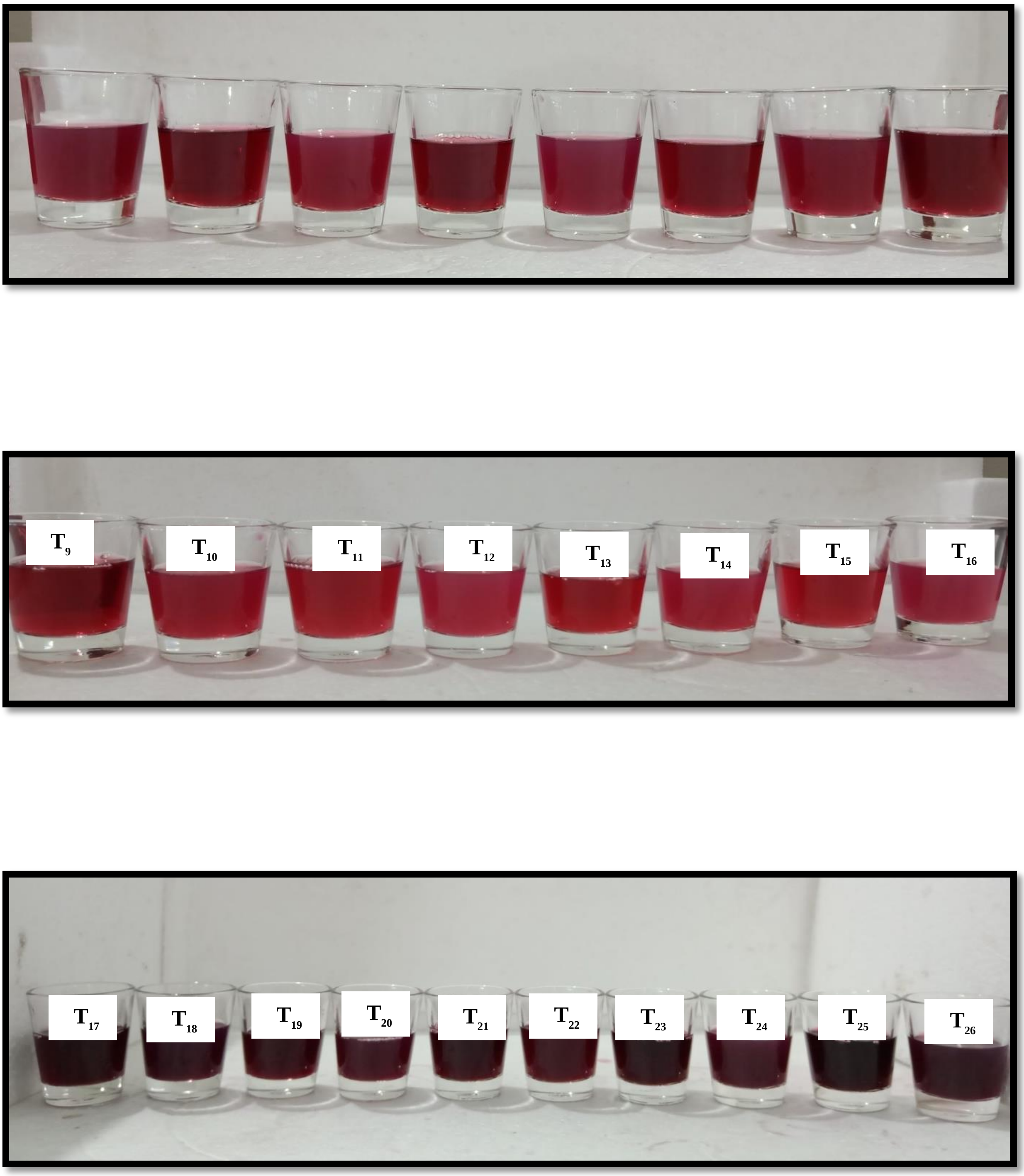


Plate 3. Jamun wines

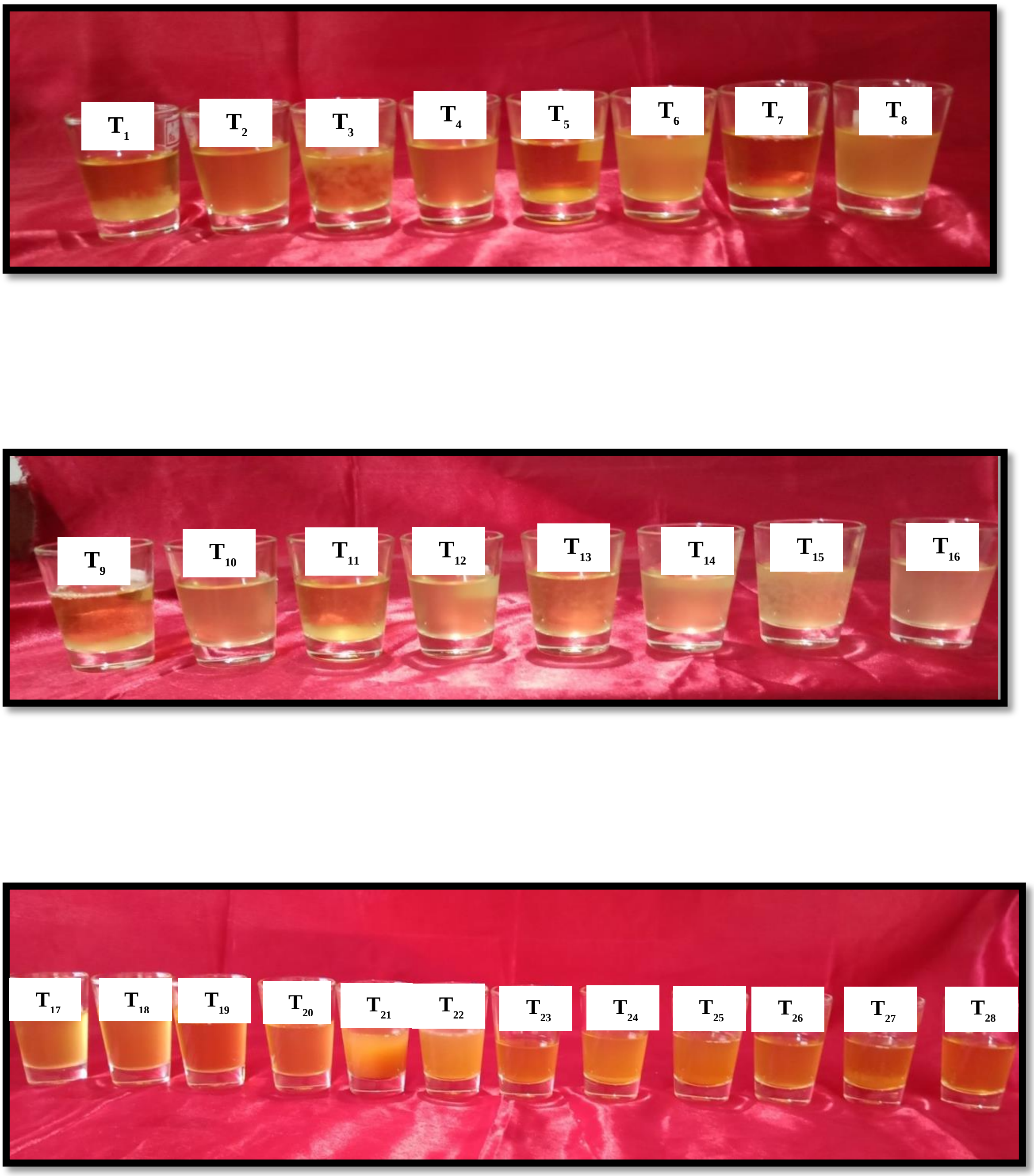


Plate 4. Papaya wines

Plate 5. Rose apple wines

Fermentation efficiency of different jamun wines ranged between 46.80% to 245.72%. Fermentation efficiency varied between 56.20% to 310.63% and 40.72% to 263.96% in papaya and rose apple wines respectively. Highest fermentation efficiency was recorded in jamun and rose apple wines with 1:0.07 fruit: water ratio and with the addition of nitrogen source. This was in the line with the findings of Vikas *et al*. (2011) who had reported that fermentation efficiency increased with addition of DAHP irrespective of dilutions.

Yield of jamun, papaya and rose apple wines ranged between 71.8% to 95.4%, 42.2% to 90.7% and 82.24% to 93.33% respectively. The highest yield was recorded in jamun, papaya and rose apple wines with 1:2 fruit: water ratio.

The TSS content of the jamun, papaya and rose apple wines varied from 4.6° Brix to 52.4° Brix, 5° Brix to 49.2° Brix and 4.6° Brix to 49.8° Brix respectively. The highest TSS content was recorded in jamun, papaya and rose apple wines with 1:0.07 fruit: water ratio and 1:1 fruit: sugar ratio. This was in line with the findings of Joshi *et al*. (2012b) who had revealed a significant reduction in TSS with increase in dilution level of jamun wines. Significantly higher TSS content was recorded with higher initial sugar concentration in the must of cashew apple (Attri, 2009).

The acidity content of all the three (jamun, papaya and rose apple) wines ranged from 0.6% to 1.1%, 0.4% to 1.4% and 0.6% to 1.24% respectively. The highest acidity content was recorded in jamun and rose apple wines with 1:0.07 fruit: water ratio. Significant reduction in acidity content was reported with increase in dilution level of wild apricot wines (Joshi *et al*., 1990). Acidity has an important role in determining the quality of the wine by regulating fermentation, improving the balance and overall characteristic traits of wine (Berry, 2000).

Reducing and total sugars of the different jamun wines ranged between 0.59 g $100g^{-1}$ to 14.95 g $100g^{-1}$ and 3.05 g $100g^{-1}$ to 46.50 g $100g^{-1}$ respectively. Reducing and total sugars of papaya wines varied between 1.01 g $100g^{-1}$ to 59.03 g $100g^{-1}$ and 2.38 g $100g^{-1}$ to 149.29 g $100g^{-1}$ respectively and in rose apple wines, reducing and total sugars ranged between 0.64 g $100g^{-1}$ to 15.94 g $100g^{-1}$ and 3.44 g $100g^{-1}$ to 47.26 g $100g^{-1}$ respectively. Highest reducing and total sugar content were recorded in jamun, papaya and rose apple wines with 1:0.07 fruit: water ratio. Joshi *et al*. (2012b) reported that there was significant reduction in reducing sugars with increase in dilution level of jamun wines. Lowest reducing and total sugar were recorded in papaya wines with clarified by pectinase. Similar findings reported by Joshi *et al*. (2016) who revealed that reduction in reducing and total sugar in muskmelon wines prepared using pectinase enzyme. Awe (2011) reported a drop in sugar content from 15 to 1% during the aerobic fermentation of papaya.

Alcohol content of all the three (jamun, papaya and rose apple) wines ranged from 3.52% to 26.37%, 3.52% to 26.37% and 3.52% to 24.61% respectively. High alcohol content was recorded in 1:2 fruit: water ratio as compared to 1:1 fruit: water ratio in all the three wines. There was significant increase in ethanol content with increase in dilution level of wild apricot wines and jamun wines (Joshi *et al*., 1990 and Joshi *et al*., 2012b). In a study by Vikas *et al*. (2011), the custard apple wine of 1:4 dilution with DAHP recorded higher alcohol content compared to 1:3 and 1:2 dilution with DAHP. Fruit wines usually have an alcohol content varying between 5 and 13% (Joshi *et al*., 2012a). Maragatham and Panneerselvam (2011) reported that there was an increasing trend in alcohol content of papaya wine during fermentation. Higher alcohol content was recorded in rose apple wines prepared with nitrogen source. Earlier findings reported a higher ethanol content in muskmelon wine produced using DAHP (Joshi *et al*., 2016).

Polyphenol content of jamun, papaya and rose apple wines varied from 95.93mgg^{-1} to 253.29mgg^{-1}, 28.4mgg^{-1} to 106.83mgg^{-1} and 36.66mgg^{-1} to 154.12mgg^{-1} respectively. High polyphenol content was recorded in 1:1 fruit: water ratio as compared to 1:2 fruit: water ratio in papaya wines. Joshi *et al*. (2016) reported that higher phenol content was observed in muskmelon wine prepared with 1:0.5 dilution of pulp as compared to 1:1 dilution of pulp. The antioxidant activity of all the three (jamun, papaya and rose apple) wines ranged from 56.2% to 95.64%, 12.44% to 87.57% and 11.03% to 83.72% respectively. Highest antioxidant activity was recorded in jamun wines produced with 1:2 fruit: water ratio as stated by Das, 2019. Mena *et al*. (2012) reported that the phenolic compounds greatly contribute to the sensory properties by affecting the colour, astringency and aroma. The antioxidant activity of wines is attributed by bioactive compounds especially polyphenols (Rivero Perez *et al*., 2008).

All the three (jamun, papaya and rose apple) wines prepared with 1:1 and 1:2 fruit: water ratio using 20% sugar irrespective of nitrogen source was contaminated. In addition to this jamun wines prepared with 1:0.07 fruit: water ratio by maintaining 24° brix and with nitrogen source were also contaminated and hence discarded

5.2 SELECTION OF THE SUPERIOR FRUIT WINES

No food or beverage is worth producing, distributing, or marketing without having an acceptable sensory quality (Tuorila and Monteleone , 2009). Sensory evaluation, a critical component for determining wine quality plays an important role in quality control and marketing of products. Consumer preferences for wine selection depend on several properties such as pleasant color, taste, aroma, ecological production, guaranteed origin, quality, and sensory perceptions (Saurina, 2010). Number of methods in the form of hedonic scales and analytical techniques like GCMS has been developed for sensory evaluation (Amerine and Roessler 1976; Reynolds, 2010). When the prepared wines were analysed for sensory quality parameters, none of the wines had high scores for all the quality parameters and hence the total sensory score of wines were calculated. Based on alcohol content, wines are classified into light with 7-9% alcohol, medium with 9-16% alcohol and strong with 16-21% alcohol content. But the wines should have low alcoholic content of less than 7% if to be marketed in Kerala as per the FSSAI regulation of Kerala State Government. An important quality parameter deciding therapeutic and nutritional property of wine is its antioxidant potential. Hence, three high yielding wines with superior antioxidant activity, total sensory score and with low alcoholic content (<7%) were selected from each fruit.

As the objective of the study was to compare the quality parameters of wines prepared by three different methods viz., common household method, the technology standardised based on previous experiment conducted in the Department and new recommendation given by FSSAI, the parameters of the selected superior wines were compared.

Common household technique of wine production involves usage of fruit: water: sugar in 1:1:1 ratio, clarification by settling with no addition of any nitrogen source. Jamun wine produced by common household practice viz., 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by settling had 89.2% yield, 4.39% alcohol content, low antioxidant activity (65.69%) with least appearance score (1.5) and total sensory score of 16.

Replacement of settling with pectinase, addition of nitrogen source and use of pectinase and doubling the water content in addition to use of pectinase and nitrogen source to the traditional household method had resulted in enhanced quality parameters and hence these three wines selected for further studies.

When clarification is replaced by pectinase (wine prepared using 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by pectinase) had 92.9% yield, 3.52% alcohol and 93.03% antioxidant activity with the highest total sensory score (18.5) and rated as extraordinary. Egwim *et al.* (2013) reported that addition of pectinase increased the organoleptic evaluation of banana and paw-paw wines. Sevda *et al.* (2011) reported that pectinase treated banana produced better quality wine as compared to wine prepared without enzyme treatment. Wine produced using 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase had 3.52% alcohol, highest (95.4%) yield and high antioxidant activity (92.5%). Joshi *et al.* (2012b) showed that jamun wine with 1:1 dilution was considered best as table wine due to good appearance, colour, total acidity, sweetness, body and overall impression. The highest antioxidant activity (95.64%) was obtained for the wine produced using 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase. This wine had 92.8% yield and 5.86% alcohol (Fig.1a-1d). Das (2019) reported that wines prepared with 1:2 fruit: water ratio had highest antioxidant activity.

Addition of nitrogen source alone or addition of nitrogen source and doubling water in household method of wine production, resulted in wines a comparatively less antioxidant activity compared to the selected wines.

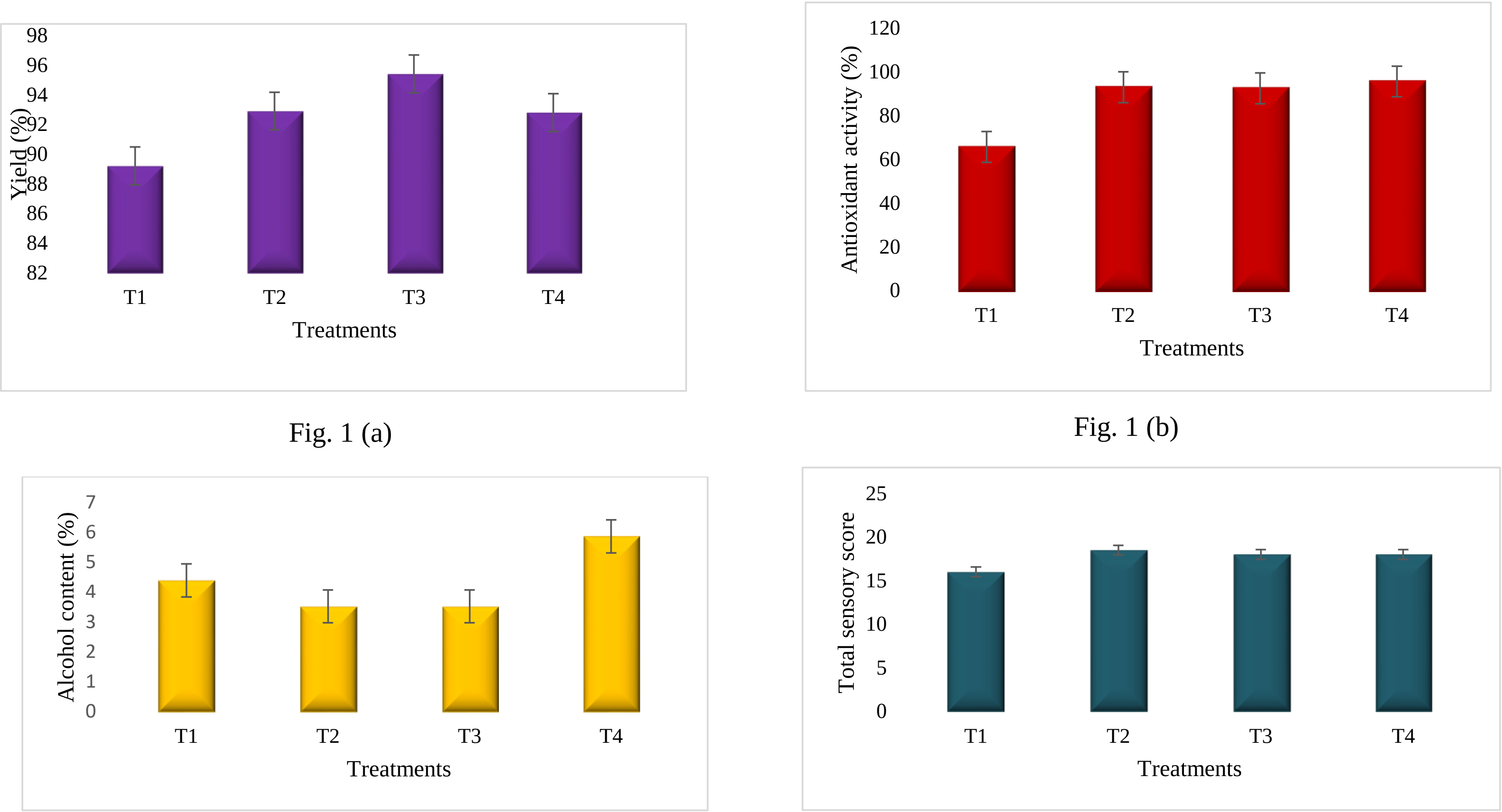


Fig. 1 (a)

Fig. 1 (b)

Fig. 1 (c)

Fig. 1 (d)

T_1 – 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source, clarified by settling

T_2 – 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source, clarified by pectinase

T_3 – 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source, clarified by pectinase

T_4 – 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source, clarified by pectinase

Figure 1 (a-d) Comparison of superior jamun wines with wine prepared by common household method

Papaya wine produced by common household method had 7.69% alcohol, 74% yield, 23.81 g $100g^{-1}$ reducing sugar and 86.67% antioxidant activity with total sensory score of 14.5.

Papaya wine produced by addition of nitrogen source to household method (1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by settling) had 87% yield, 4.39% alcohol, 20.41 g $100g^{-1}$ reducing sugar and 86.93% antioxidant activity. Joshi *et al.* (2016) reported that muskmelon wine prepared using DAHP had low reducing sugar compared to the muskmelon wine prepared without DAHP. Wine produced with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase had highest total sensory score (17) and rated as excellent, 3.52% alcohol, and 86.54% antioxidant activity. Wine prepared with 1:2 fruit: water ratio, 1:1 fruit: sugar, with nitrogen source and clarified by pectinase had 90.7% yield, 5.13% alcohol, 82.95% antioxidant activity and had high total sensory score (15.5) hence these three superior wines selected for storage study (Fig.2a-2d). Clarification by pectinase had resulted in increased yield and organoleptic evaluation of banana and paw-paw wines as reported by Egwim *et al.* (2013).

Rose apple wine prepared by adopting household method (1:1 fruit: water ratio, 1:1 fruit: sugar, without nitrogen source and clarified by settling) had 92.33% yield, 3.52% alcohol and 75.12% antioxidant activity with highest total mean sensory score (16) and rated as excellent. Pink rose apple wine produced with fruit: sugar: water ratio of 1:1:1 recorded highest score for taste in sensory evaluation (Bolarin *et al.*, 2016). Preparation of wine with 1:1 fruit: water ratio, 1:1 fruit: sugar, with nitrogen source and clarified by pectinase had resulted in wine with 91.33% yield, 3.52% alcohol and 80.13% antioxidant activity. The wine produced using 1:2 fruit: water ratio, 1:1 fruit; sugar ratio, without nitrogen source and clarified by settling had highest (93.33%) yield, 4.39% alcohol, 83.33% antioxidant activity and highest total sensory score (16) and rated as excellent, hence selected for storage study (Fig.3a-3d). When the dilution level increased, Joshi *et al.* (2012b) reported that there was an increase in alcohol content.

By addition of pectinase alone in household method could produce rose apple wine with less antioxidant activity. It was seen that adoption of settling for clarification was better in rose apple wine. This was in agreement with the findings of Das, 2019.

In general, wines prepared from must of 1:1 and 1:2 fruit: water ratio along with 1:1 fruit: sugar ratio had superior quality and acceptability (Plate 6a-6c and Plate 7a-7c). The highest antioxidant activity was recorded in wines of papaya and rose apple produced using 1:1 fruit: water ratio and 1:1 fruit: sugar ratio. Wines with 1:2 fruit: water ratio and 1:1 fruit: sugar ratio had highest antioxidant activity in case of jamun wines. The alcohol content of all the selected wines was increased with increase in dilution level. The rate of fermentation, alcohol content and pH of the wild apricot wines increased with increase in the dilution levels (Joshi *et al.*, 1990). Thick pulp and high acidity of fruits affect their fermentation and hence the quality of product (Shukla *et al.*, 1991). Jamun wine prepared with 1:1 dilution was observed as the best due to optimum TSS, acidity, alcohol content, appearance, colour, sweetness, body and overall impression (Joshi et al., 2012b).

Nitrogen is a key factor that has a significant impact on wine fermentation. It is the most important yeast nutrient, influencing both fermentation kinetics and wine quality. The aromatic composition of the wines improved with the addition of inorganic nitrogen, although its organoleptic evaluation was not favoured (Santamaria *et al.*, 2020). Addition of nitrogen source increases the rate of fermentation in all the selected superior wines (Plate 8a-8c). Addition of DAHP (0.1%) enhanced the rate of fermentation irrespective of dilution levels. The quality of wine was not altered significantly by the addition of nitrogen source (Joshi *et al.*, 1990). Addition of nitrogen source enhanced the fermentation efficiency of jamun and rose apple wines but did not enhance in case of papaya wines. Vikas *et al.* (2011) reported that fermentation efficiency and alcohol content were increased, with addition of DAHP irrespective of dilutions in custard apple wine.

The biological process of winemaking is the result of a series of biochemical transformations caused by the action of several enzymes. Many of these enzymes originate from the grapes, yeasts and other microorganisms are often neither efficient nor sufficient under winemaking conditions. Commercial enzymes are also widely used as supplements. The addition of commercial enzymes (i.e. pectinases, xylanases, glucanases, proteases) improve clarification and filtration in winemaking

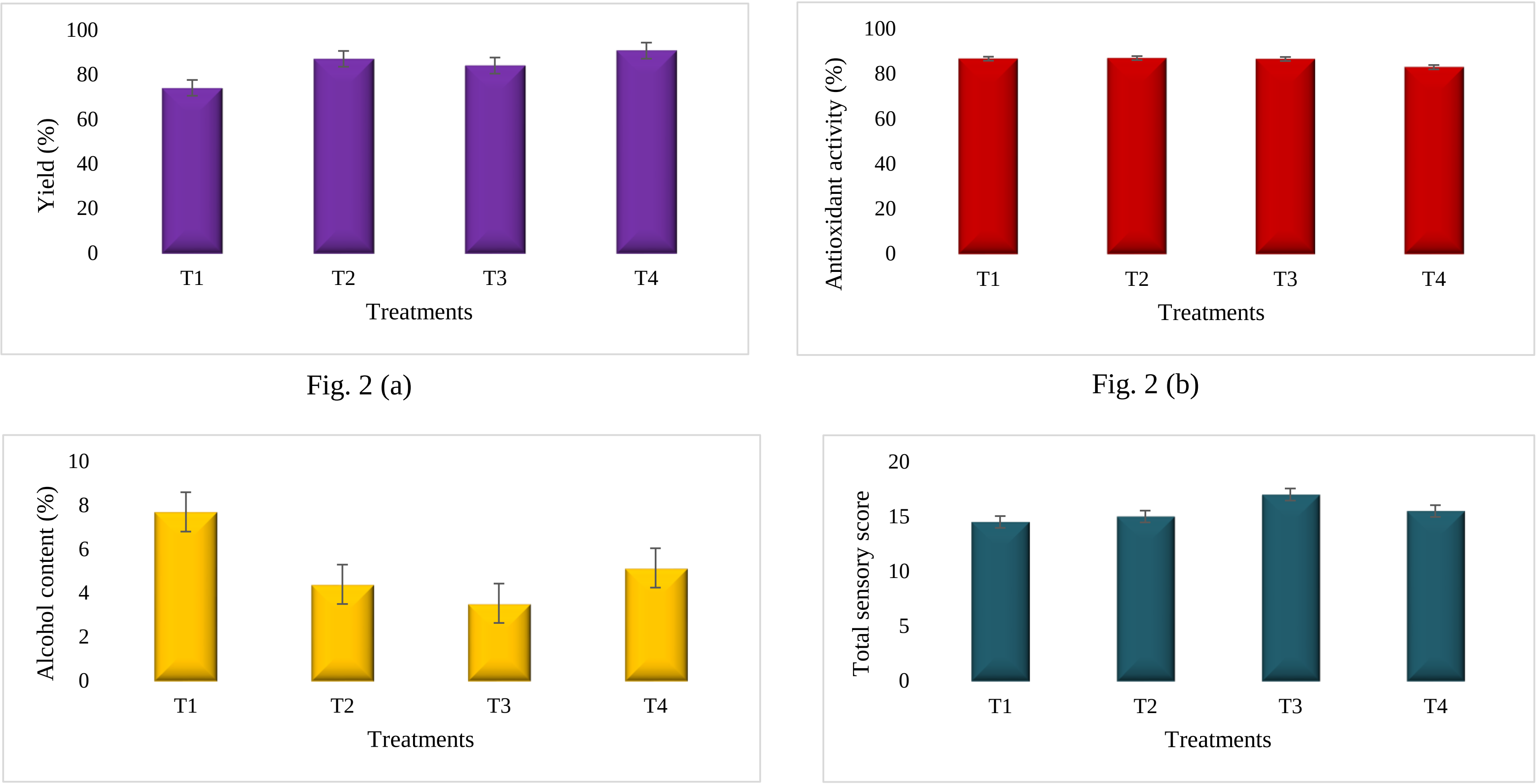


Fig. 2 (a)

Fig. 2 (b)

Fig. 2 (c)

Fig. 2 (d)

T_1 – 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source, clarified by settling

T_2 – 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source, clarified by settling

T_3 – 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source, clarified by pectinase

T_4 – 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source, clarified by pectinase

Fig. 2 (a-d) Comparison of superior papaya wines with wine prepared by common household method

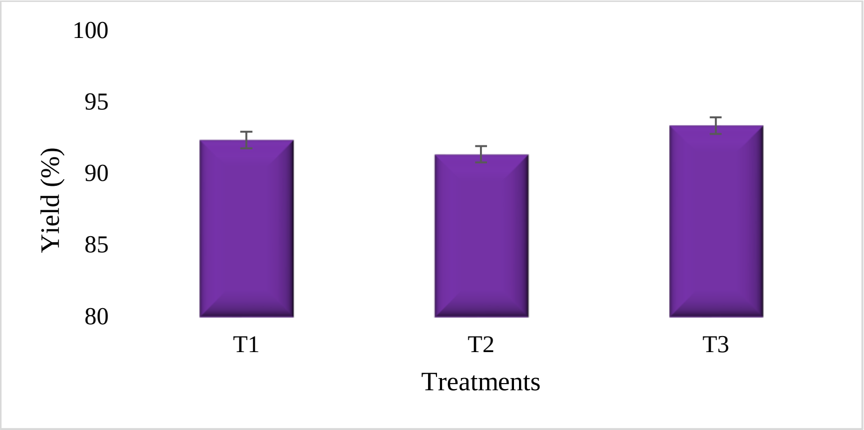


Fig. 3 (a)

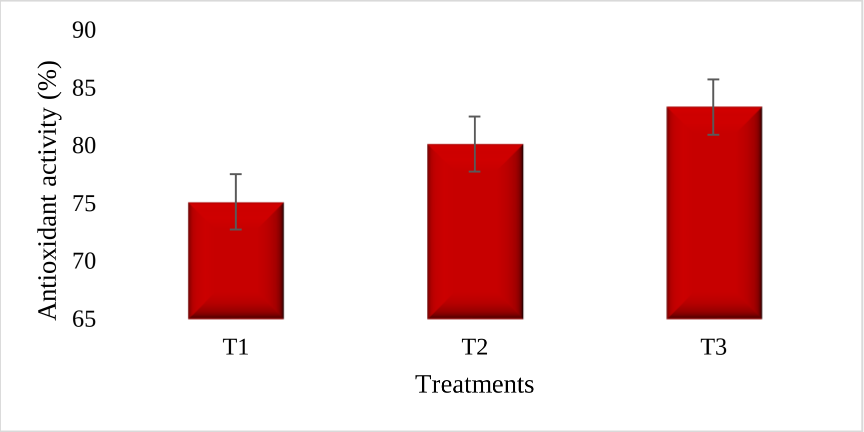


Fig. 3 (b)

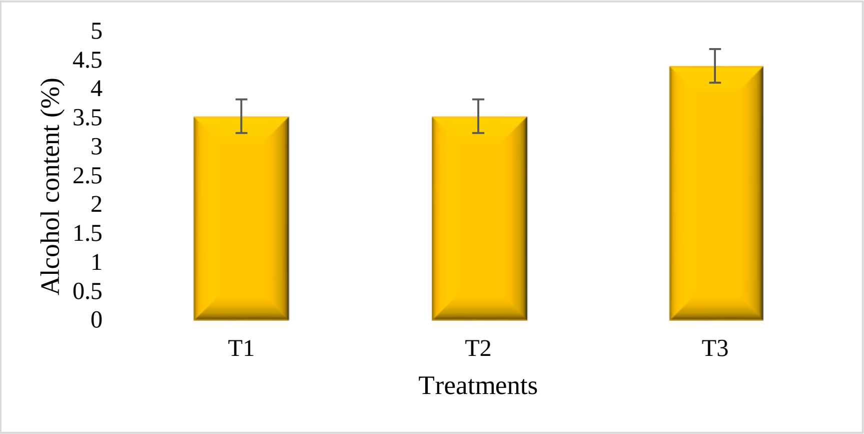


Fig. 3 (c)

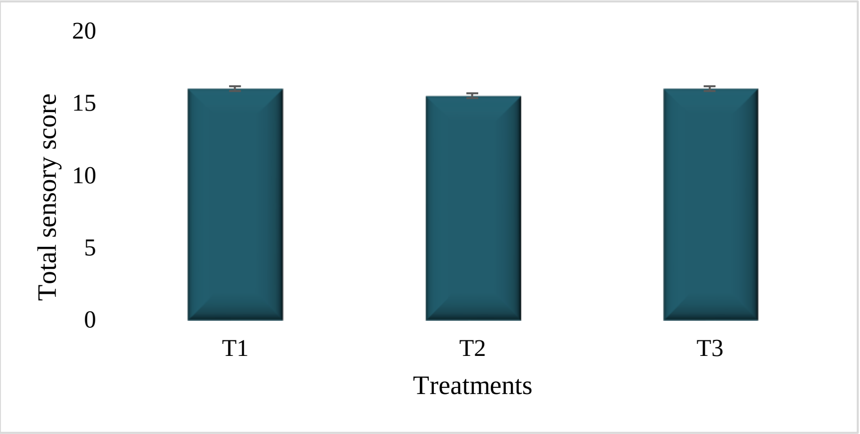


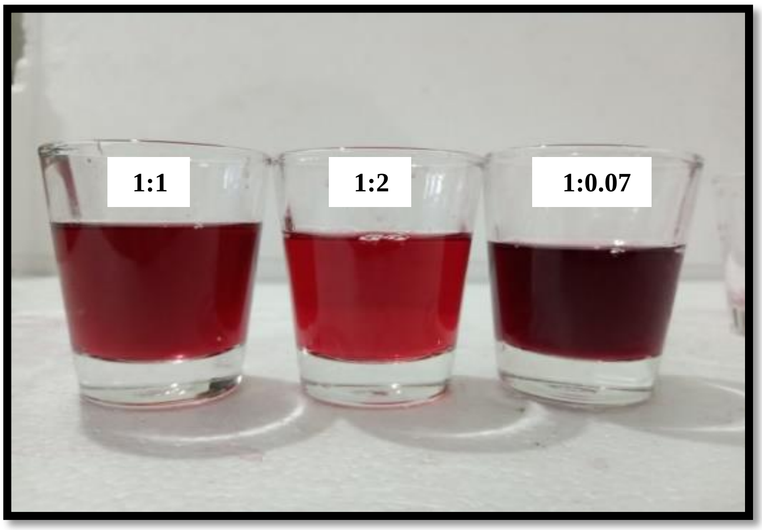
Fig. 3 (d)

T_1 – 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source, clarified by settling

T_2 – 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source, clarified by pectinase

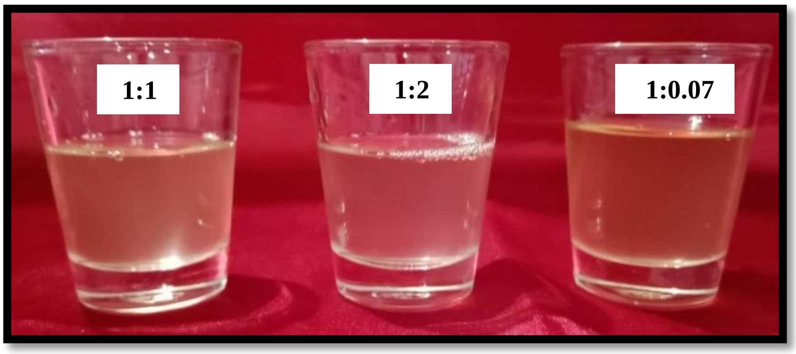
T_3 – 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source, clarified by settling

Fig. 3 (a-d) Comparison of superior rose apple wines with wine prepared by common household method



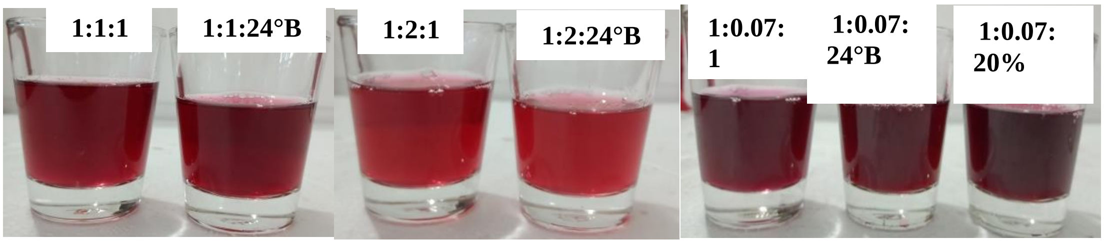
6 (a) Jamun

6 (b) Papaya

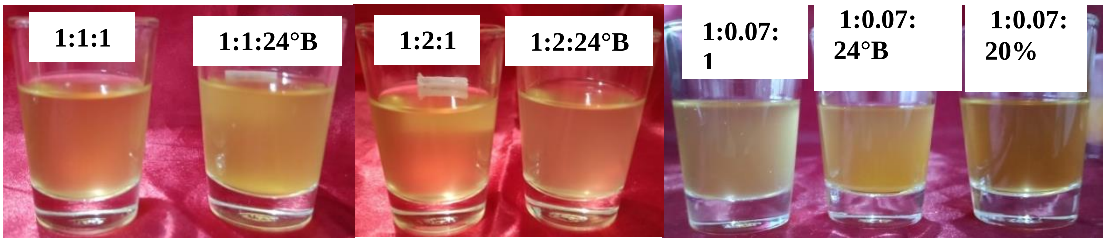


6 (c) Rose apple

Plate 6(a-c) Effect of Fruit : Water ratio on the quality of fruit wines



7 (a) Jamun



7 (b) Papaya

\

7 (c) Rose apple

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

8(a) Jamun

8 (b) Papaya

8 (c) Rose apple

Plate 8(a-c) Effect of nitrogen source on the quality of fruit wines

process. Pectinase breaks down pectins which gives improved yield of juice when pressing, produces faster settling of juice, and may also release more aromatic constituents and increase the extraction of colour components. These are the enzymes most useful to the winemaking process. Use of pectinase was necessary for clarifying jamun and papaya wines (Plate 9a-9b). Thick flesh of jamun and pulp of papaya could be clarified efficiently by use of pectinase. Pectinase helps in hydrolysis of structural polysaccharides (pectins, cellulose and hemicelluloses), improvement of skin maceration and colour extraction, aroma compounds, flavour enhancement and stability of wines (Espejo, 2021). Clarification by settling itself could give a good quality wine from rose apple, which is watery or juicy in nature (Plate 9c).

All the three (jamun, papaya and rose apple) wines produced with 1:1 and 1:2 fruit: water ratio, by maintaining 24° brix had high alcohol content (more than 7%) irrespective of nitrogen source and clarification methods. Vikas *et al.* (2011) reported that the custard apple wine of 1:4 dilution with DAHP recorded higher alcohol content of 8.14 v/v compared to 1:3 dilution with DAHP (8.06 v/v) and 1:2 dilution with DAHP (8.03v/v).

All the three (jamun, papaya and rose apple) wines produced using 1:0.07 fruit: water ratio had low sensory scores which were obtained as less acceptability. This was in the line findings of Joshi *et al.* (2012b) who had reported that the wines fermented from must with lower dilutions scored lower sensory score compared to other with higher dilutions.

5.3 STORAGE STABILITY OF SELECTED FRUIT WINES

Ageing of wines in bottles is subjected to oxidative reactions if the bottle closures allow oxygen to enter into the wine. The factors like temperature, oxygen content and light may affect the qualitative characteristics of aroma, colour and phenolic composition during the storage period (Chira *et al.*, 2012). 'Wine faults' formulate when direct sunlight reacted adversely with phenolic compounds in wine. There exists no ideal storage temperature for wine in general due to a careful balance between complexity and maturity during wine production and prevention of qualitative characteristics from taking hold. But the wine will distinctly benefit from a reduced risk of spoilage which takes a longer time to develop when the temperature is low (e.g. < 10°C) (Scrimgeour, 2015). Wines stored at low temperature ages much slower and usually have better flavours and tastes (De LA Persa-Owens and Noble, 1997).

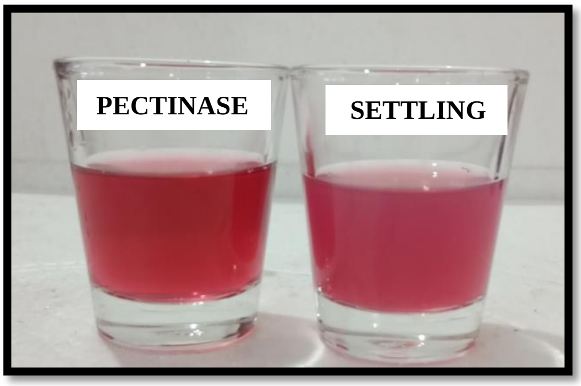
The three superior wines selected from each fruit were stored under ambient storage condition for a period of two months in amber coloured glass bottles for analysing the storage stability. Quality parameters viz., polyphenol and alcohol content of the superior wines were analysed initially and after two months of storage.

The polyphenol content of all the three (Jamun, papaya and rose apple) wines decreased during maturation (Fig. 4a-4c). Similar findings reported by Chaudhary *et al.* (2015) stated that phenol content decreased after storage of two months. The acceptability of wine increased on prolonged storage due to reduction of phenolic compounds and yeast odour on storage (Sharma and Joshi, 2003 and Chaudhary *et al.*, 2017). Decreased phenol concentration is due to the susceptibility of phenolic constituents to degradation, condensation and polymerization, and subsequent precipitation (Zoecklein *et al.*, 1995).

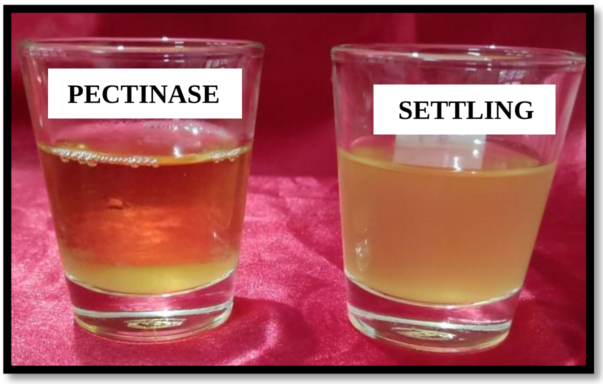
The alcohol content of jamun wine decreased during ageing (Fig. 5a) as stated by Joshi *et al.* (2012b). Zoecklein *et al.* (1995) reported that decreased ethanol content during ageing is apparently the results of interaction between alcohols and acids to form esters. Alcohol content of papaya and rose apple wines increased during storage (Fig. 5b-5c). Similar increase in alcohol content was reported in pomegranate and sweet lovi-lovi wines after three months of storage (Ulla, 2011 and Sebastian *et al.*, 2019).

As per FSSAI specification, presence of coliform bacteria is considered problematic in fruit wines. All the selected wines were free from coliform bacteria indicating that they were safe at the two month of storage.

Main aim of packaging is the protection and maintenance of the original quality of the food as much as possible. Primary physicochemical parameters that allow the package to achieve its purpose are oxygen, carbon dioxide, moisture, light and aroma-binding properties. Glass is the classical packaging material for wine



9 (a) Jamun



9 (b) Papaya

9 (c) Rose apple

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

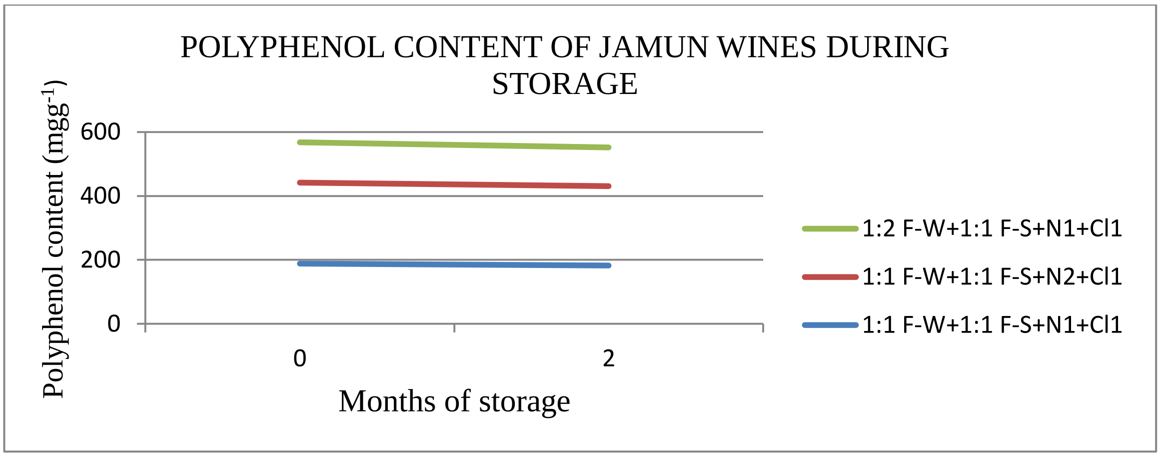


Fig. 4 (a)

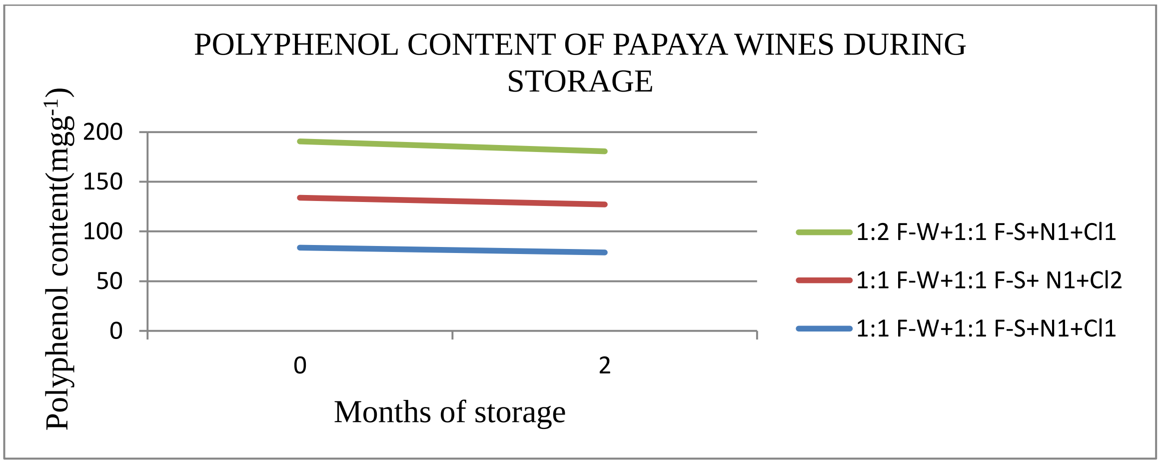


Fig. 4 (b)

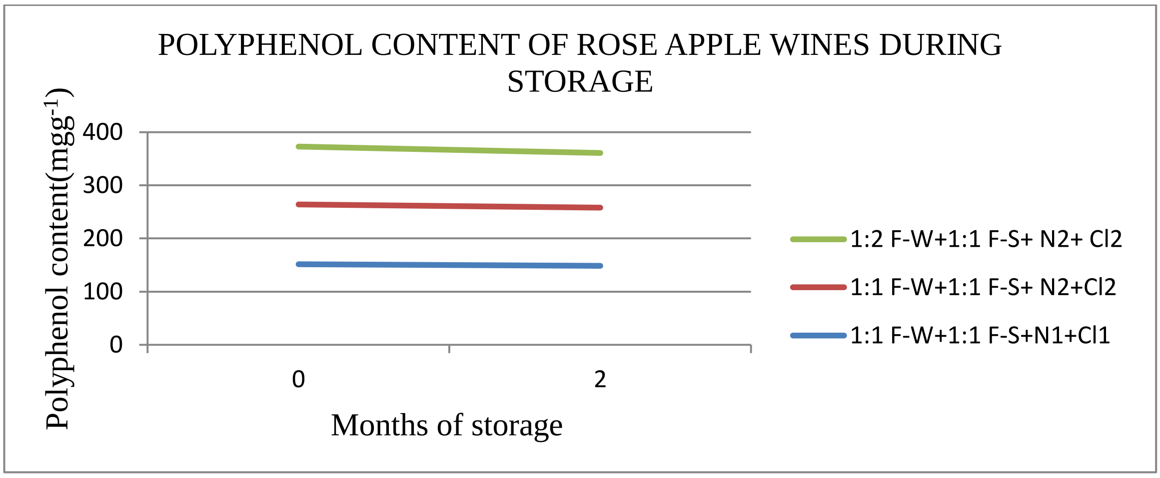


Fig. 4 (c)

F-W – Fruit: water ratio F-S – Fruit: sugar ratio N_1 – With nitrogen source
N_2 – Without nitrogen source Cl_1 – Clarified by pectinase Cl_2 – Clarified by settling

Fig. 4 (a-c) Polyphenol content of selected wines during storage

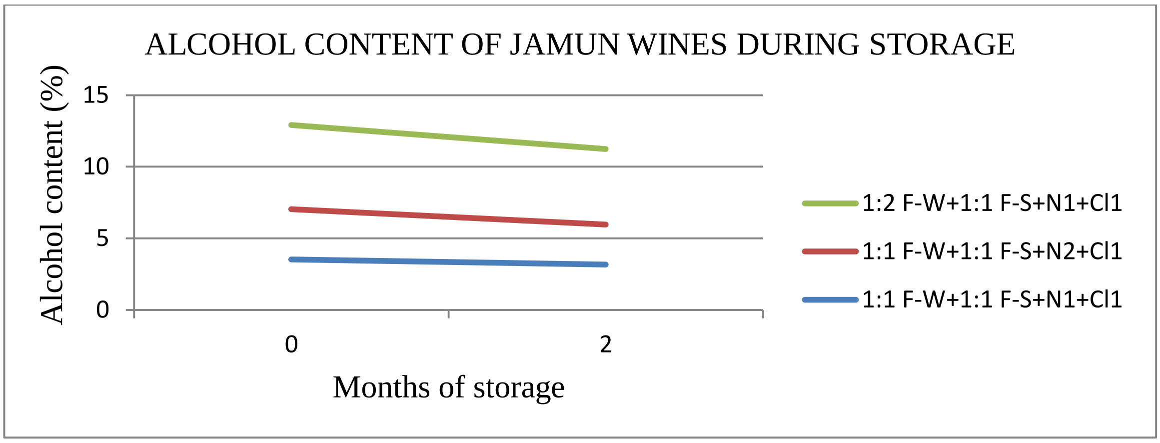


Fig. 5 (a)

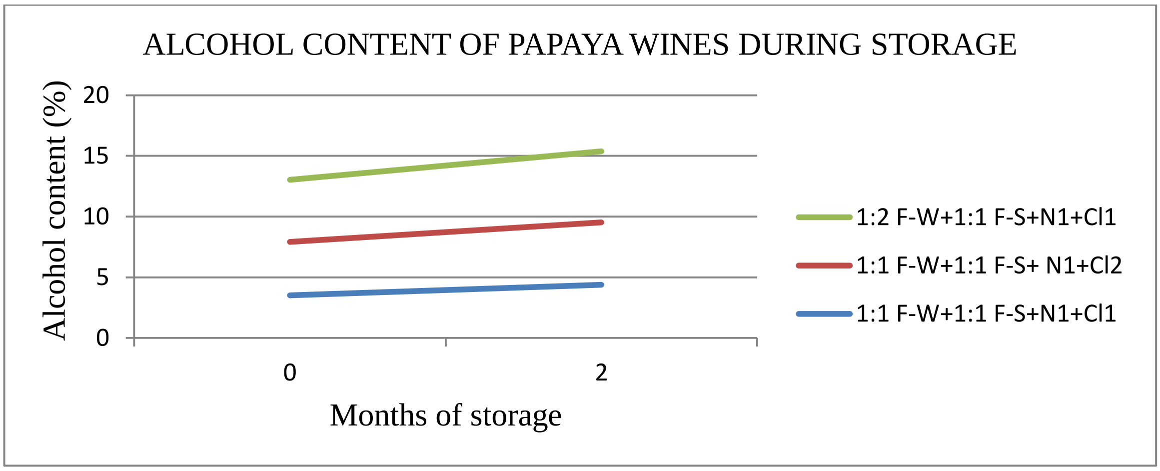


Fig. 5 (b)

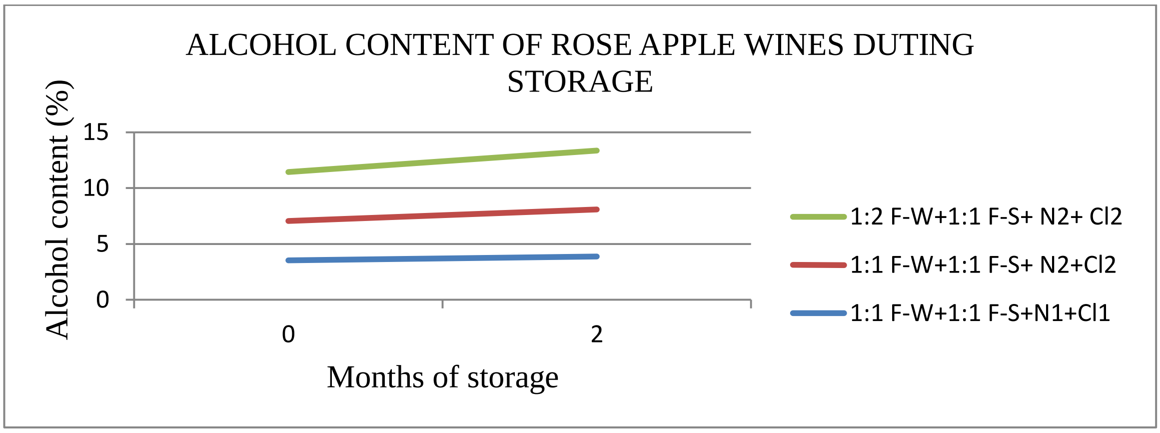


Fig. 5 (c)

F-W – Fruit: water ratio F-S – Fruit: sugar ratio N_1 – With nitrogen source
N_2 – Without nitrogen source Cl_1 – Clarified by pectinase Cl_2 – Clarified by settling

Fig. 5 (a-c) Alcohol content of selected wines during storage

because of the inactivity and clarity. Amber and green coloured dark bottles offer greater protection from light than clear and light coloured bottles (Grant-Preece *et al.*, 2017).

In general, utilization of pectinase for clarification, addition of nitrogen source and clarification by pectinase or by doubling the water content in addition to nitrogen source and use of pectinase can improve yield, antioxidant property and sensory score of jamun wine. Addition of nitrogen source, use of pectinase and nitrogen source or doubling the water content with nitrogen source and use of pectinase can improve yield and sensory score of papaya wine. But alcohol content and antioxidant activity were significantly reduced by doubling water in addition to use of nitrogen source and pectinase. By doubling the water content or usage of a nitrogen source and pectinase enzyme, no significant improvement could be made in yield or alcohol content of rose apple wine; instead the antioxidant activity could be significantly improved.

Summary

6. SUMMARY

The present study entitled “Technology refinement for wine production from under exploited fruits” was conducted at Department of Post Harvest Technology, Kerala Agricultural University, College of Agriculture, Vellayani, Thiruvananthapuram, during the year 2019-2021 with the objective for technology refinement for wine production from under exploited fruits based on quality parameters and storage stability.

Fruit wines were prepared from three underexploited fruits viz., jamun, papaya and rose apple independently by varying the process parameters viz., fruit: water ratio, fruit: sugar ratio, nitrogen source and clarification methods. Fruit: water ratio was tried at 1:1, 1:2 and 1.0.07; fruit: sugar ratio was maintained at 1:1, 24° brix and at 20% sugar, with or without nitrogen source, thus forming 18 different wines under each fruit. The resultant 18 different fruit wines after primary fermentation were analysed for physical quality parameters and subjected to clarification by pectinase enzyme and by settling, thus forming 36 different wines under each fruit.

The study was conducted as four continuous steps *viz*., fruit wine preparation, quality analysis of fruit wines, selection of the superior wines and evaluation of storage stability. The important findings of the study are summarized as follows.

6.1. Jamun

Jamun (*Syzygium cumini*) could be processed into attractive dark purple wines with a fermented yield of 71.8 to 95.4 per cent.

There was no significant difference between the rate of fermentation and fermentation efficiency of wines produced with and without nitrogen source.

The highest rate of fermentation (0.056°Brix/24 hours) was obtained for the jamun wine prepared with 1:2 fruit: water ratio, maintaining 24° brix and with nitrogen source. The lowest rate of fermentation (0.013°Brix/24 hours) was obtained for wine produced with 1:0.07 fruit: water ratio, 1:1 fruit: sugar ratio and without nitrogen source.

The highest fermentation efficiency (245.72%) was recorded in the jamun wine produced using 1:2 fruit: water ratio, 20% sugar and with nitrogen source. The lowest fermentation efficiency (46.80%) was recorded in wine prepared with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio and without nitrogen source.

Wines prepared with 1:1 and 1:2 fruit: water ratio with 20% sugar irrespective of nitrogen source & 1:0.07 fruit: water ratio by maintaining 24° brix and with nitrogen source were contaminated and hence discarded.

Acidity content was significantly influenced by interaction effect of process parameters.

Wine produced by common household practice viz., 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by settling had 89.2% yield with 23° brix TSS, 0.7% acidity, 182.19mgg^{-1} polyphenol content, 65.69% antioxidant activity, 4.39% alcohol content, but had least sensory score for appearance (1.5).

Addition of a nitrogen source to the common household practice, resulted in wine with similar acidity and alcohol content, increased yield (91.9%), TSS (27.9° brix) and antioxidant activity (89.7%), low polyphenol content (179.19 mgg^{-1}) compared to wine produced by common household method.

When settling in common household practice is replaced with clarification by pectinase, the resulting wine had similar acidity, sugars and alcohol content as that of wine produced by common household method, but with high yield (92.9%), TSS (23.9° brix), antioxidant activity (93.03%) and polyphenol content (253.29mgg^{-1}) with highest total sensory score (18.5) and rated extraordinary.

The wines produced using 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, clarified by pectinase and with nitrogen source had high antioxidant activity (92.5%), polyphenol (188.28mgg^{-1}) and highest yield (95.4%), low alcohol content (3.52%) with highest score for appearance (3.0) and after taste (2.7).

When 1:1 fruit: water ratio in common household practice is changed to 1:2, the resulting wine had similar acidity and alcohol content as that of wine produced by common practice, but with high antioxidant activity (86.23%) and yield (89.6%), low TSS (13° brix) and polyphenol content (95.93mgg^{-1}) with an appearance score of 1.9.

Addition of nitrogen source and replacing fruit: water ratio with 1:2 in common household practice resulted in wine with similar acidity (0.6%) and alcohol content (6.59%), reduced yield (85.9%) and TSS (13.8° brix), high antioxidant activity (78.86%) and polyphenol content (187.28mgg^{-1}) compared to wine prepared by common method.

When 1:1 fruit: water ratio and clarification by settling were replaced with 1:2 fruit: water ratio and clarification by pectinase, the resulting wine had similar acidity and alcohol content as that of wine produced by common household method. But it had high antioxidant activity (93.36%), low TSS (13.4° brix), polyphenol content (107.28mgg^{-1}) and yield (85.7%).

Wine produced using 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase had similar acidity and alcohol content as that of wine produced by common household method, but had highest antioxidant activity (95.64%), yield (92.8%), low TSS (13.6° brix) and polyphenol content (125.92mgg^{-1}) with highest score for appearance (3.0) and after taste (2.7).

All wines produced with 1:1 and 1:2 fruit: water ratio, by maintaining 24° brix had high alcohol range of 10.55% to 14.06% and 13.18% to 15.82% respectively, irrespective of nitrogen source and clarification methods.

Wines produced using 1:0.07 fruit: water ratio and 1:1 fruit: sugar ratio had low alcohol content of 3.52% to 5.27% and high TSS content of 49.6° brix to 52.4° brix, irrespective of nitrogen source and clarification methods.

All wines produced with 1:0.07 fruit: water ratio, maintaining 24° brix and without nitrogen source irrespective of clarification methods and wines prepared with 1:0.07 fruit: water ratio, 20% sugar irrespective of nitrogen source and clarification methods had very high alcohol range of 11.06% to 12.18% and 9.36% to 13.36% respectively.

Three high yielding wines with superior antioxidant activity and total sensory score were selected for storage study. Wine produced using 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by pectinase, wine prepared with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase and wine prepared with 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase were selected and stored in amber coloured glass bottles under ambient condition for a period of two months for analysing the storage stability.

6.2 Papaya

Papaya (*Carica papaya*) could be processed into papaya flavoured light yellowish wines with fermented yield of 42.2 to 90.7 per cent.

There was no significant difference between the rate of fermentation and fermentation efficiency of wines prepared with and without nitrogen source.

The highest rate of fermentation (0.051°Brix/24 hours) was recorded in the papaya wine produced using 1:2 fruit: water ratio, maintaining 24° brix and without nitrogen source. The lowest rate of fermentation (0.012°Brix/24 hours) was recorded in wine produced with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio and without nitrogen source.

The highest fermentation efficiency (310.63%) was recorded in the papaya wine produced using 1:0.07 fruit: water ratio, 1:1 fruit: sugar ratio and without nitrogen source. The lowest fermentation efficiency (56.20%) was recorded in wine produced with 1:2 fruit: water ratio, 1:1 fruit: sugar ratio and without nitrogen source.

Wine prepared with 1:1 and 1:2 fruit: water ratio with 20% sugar were contaminated irrespective of nitrogen source and hence discarded.

Acidity of the papaya wines was not significantly influenced by the process parameters.

Wine produced by common household practice viz., 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by settling had 26.4° brix TSS, 1.4% acidity, 7.69% alcohol content, 52.74mgg^{-1} polyphenol content, 86.67% antioxidant activity and 74% yield, but had least score for appearance (1.8) and high score for taste/texture (4.7).

Addition of a nitrogen source to the common household practice, resulted in wine with increased yield (87%) and antioxidant activity (86.93%) had similar TSS and acidity, low alcohol (4.39%) and polyphenol content (50.19mgg^{-1}) compared to wine produced by common household method.

When settling in common household practice is replaced with clarification by pectinase, the resulting wine had similar TSS, acidity and alcohol content as that of wine produced by common practice. But it had highest antioxidant activity (87.57%), high yield (81.7%) and polyphenol content (62.51mgg^{-1}).

The wines produced with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase had least alcohol content (3.52%), high antioxidant activity (86.54%), polyphenol content (83.65mgg^{-1}) and yield (84%) with highest score for appearance (2.9), taste/texture (5.0), after taste (2.8) and overall impression (2.0).

When 1:1 fruit: water ratio in common practice is changed to 1:2, the resulting wine had similar acidity as that of wine produced by common method, but with high yield (86%) and polyphenol content (60.83mgg^{-1}), low TSS (11.8° brix), alcohol content (5.13%) and antioxidant activity (82.82%) with an appearance score of 1.9.

Doubling the water content and addition of nitrogen source in common household method resulted in wine with similar acidity (0.6%), reduced TSS (12.2° brix), alcohol content (5.27%) and antioxidant activity (82.69%), high yield (87.3%) and polyphenol content (56.28mgg^{-1}) compared to wine prepared by common method.

When 1:1 fruit: water ratio and clarification by settling were replaced with 1:2 fruit: water ratio and clarification by pectinase, the resulting wine had similar acidity (0.4%), increased yield (74.7%), reduced TSS (12.8° brix), alcohol content (4.65%), antioxidant activity (63.2%) and polyphenol content (46.64mgg^{-1}) compared to wine prepared by common household practice.

Wine prepared with 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase had similar acidity as that of wine produced by common household method, but had high yield (90.7%) and polyphenol content (56.55mgg^{-1}), low TSS (12.4° brix), alcohol content (5.13%) and antioxidant activity (82.95%) with highest score for appearance (2.9) and aroma (4.7).

All wines produced with 1:1 and 1:2 fruit: water ratio, by maintaining 24° brix had high alcohol range of 10.55% to 16.7% and 13.18% to 16.7% respectively, irrespective of nitrogen source and clarification methods.

All wines prepared with 1:0.07 fruit: water ratio and 1:1 fruit: sugar ratio, maintaining 24° brix and 20% sugar had high alcohol range of 9.89% to 14.28%, 9.34% to 10.99% and 9.34% to 11.23% respectively, irrespective of nitrogen source and clarification methods.

Three high yielding wines with superior antioxidant activity and total sensory score selected for storage study. Wine produced using 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase, wine produced with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by settling and wine prepared with 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase and were selected and stored in amber coloured glass bottles under ambient condition for a period of two months for analysing the storage stability.

6.3 Rose apple

Rose apple (*Syzygium jambos*) could be processed into creamy white wines with 82.24 to 93.33 per cent yield.

There was no significant difference between the rate of fermentation and fermentation efficiency of wines prepared with and without nitrogen source.

The highest rate of fermentation (0.039°Brix/24 hours) was recorded in the rose apple wines produced using 1:2 fruit: water ratio, 1:1 fruit: sugar ratio and with nitrogen source. The lowest rate of fermentation (0.013°Brix/24 hours) was recorded in wines produced with 1:0.07 fruit: water ratio, 20% sugar and with or without nitrogen source.

The highest fermentation efficiency (263.96%) was recorded in the rose apple wine produced using 1:0.07 fruit: water ratio, 1:1 fruit: sugar ratio and without nitrogen source. The lowest fermentation efficiency (40.72%) was recorded in wine produced with 1:2 fruit: water ratio, 1:1 fruit: sugar ratio and without nitrogen source.

Wine prepared with 1:1 and 1:2 fruit: water ratio with 20% sugar were contaminated irrespective of nitrogen source and hence discarded.

Wine produced by common household practice viz., 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by settling had 25° brix TSS, 0.6% acidity, 3.52% alcohol content, 112.34mgg^{-1} polyphenol content, 75.12% antioxidant activity and 92.33% yield with highest score of taste/texture (5.2), after taste (2.5) and overall impression (1.7).

Addition of a nitrogen source to the common practice, resulted in wine with similar acidity and alcohol content as that of wine produced by common practice, but with decreased yield (86.33%) and antioxidant activity (64.88%), high TSS (27° brix), polyphenol content (134.93 mgg^{-1}) and highest score for overall impression (1.7).

When settling is replaced with clarification by pectinase, the resulting wine had similar TSS, acidity and alcohol content as that of wine produced by common practice, but with high polyphenol content (115.79mgg^{-1}), low yield (83%) and antioxidant activity (72.05%).

The wines produced with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase had low alcohol content (3.52%), high antioxidant activity (80.13%), polyphenol content (151.65mgg^{-1}) and yield (91.33%) with highest score for overall impression (1.7) and high score for taste/texture (5.0).

When 1:1 fruit: water ratio in common practice is changed to 1:2, the resulting wine had similar acidity and alcohol content as that of wine produced by common method, but with high yield (93.33%) and antioxidant activity (83.33%), low TSS (8.8° brix) and polyphenol content (108.66mgg^{-1}) with highest score for taste (5.2), after taste (2.5) and overall impression (1.7).

Addition of nitrogen source and replacing fruit: water ratio with 1:2 in common method resulted in wine with similar acidity (0.7%) and alcohol content (5.8%), high yield (93.33%) and low TSS (9.4° brix), antioxidant activity (72.31%) and polyphenol content (103.91mgg^{-1}) compared to wine prepared by common method.

When 1:1 fruit: water ratio and clarification by settling were replaced with 1:2 fruit: water ratio and clarification by pectinase, the resulting wine had similar acidity and alcohol content as that of wine produced by common method. But it had high polyphenol content (136.11mgg^{-1}), low TSS (9.6° brix), antioxidant activity (42.56%) and yield (83.67%) with lowest overall impression score (1.2).

Wine produced using 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase had similar acidity and alcohol content as that of wine produced by common household method, but had high polyphenol content (137.02mgg^{-1}), low yield (87.33%), TSS (10° brix) and antioxidant activity (42.69%).

All wines produced with 1:1 and 1:2 fruit: water ratio, by maintaining 24° brix had high alcohol range of 8.79% to 11.43% and 10.55% to 13.18% respectively, irrespective of nitrogen source and clarification methods.

All wines prepared with 1:0.07 fruit: water ratio and 1:1 fruit: sugar ratio, maintaining 24° brix and 20% sugar had high alcohol range of 7.91% to 8.79%, 8.79% to 10.55% and 10.55% to 11.43% respectively, irrespective of nitrogen source and clarification methods.

Three high yielding wines with superior antioxidant activity and total sensory score were selected for storage study. Wine produced using 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase, wine prepared with

1:1 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by settling and wine prepared with 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by settling were selected and stored in amber coloured glass bottles under ambient condition for a period of two months for analysing the storage stability.

When the selected wines were stored in amber coloured glass bottles under ambient condition for a period of two months for analysing the storage stability, the polyphenol content was decreased and alcohol content was increased in papaya and rose apple wines; whereas polyphenol and alcohol content were decreased during storage period.

The study clearly points out the relevance of selecting process parameters based on the quality of raw material used for wine making. Adoption of production technology based on the recommendation of FSSAI has given wines of low acceptability in the present study, which is to be further investigated for confirmation of results.

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Appendices

APPENDIX I

SCORE CARD FOR ORGANOLEPTIC EVALUATION OF FRUIT WINES

Wine Evaluation Chart

Name………………………….. Date…………………………….

Place……………………….......

Sl. No.	Sample	Appearance (3 Max)	Aroma (6 Max)	Taste/ Texture (6 Max)	After taste (3 Max)	Overall impression (2 Max)	Total Score (20 Max)

<u>Rating of total scores</u>

- 18 - 20 Extraordinary
- 15 - 17 Excellent
- 12 - 14 Good
- 9 - 11 Commercially acceptable
- 6 - 8 Deficient
- 0 - 5 Poor & Objectionable

Abstract

TECHNOLOGY REFINEMENT FOR WINE PRODUCTION FROM UNDER EXPLOITED FRUITS

by

AISWARYA S

(2019-12-029)

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

VELLAYANI, THIRUVANANTHAPURAM-695522

KERALA, INDIA

2021

ABSTRACT

The present study entitled "Technology refinement for wine production from under exploited fruits" was conducted at Department of Post Harvest Technology, Kerala Agricultural University, College of Agriculture, Vellayani during the year 2019-2021 with the objective for technology refinement for wine production from under exploited fruits based on quality parameters and storage stability.

Fruit wines were prepared from three under exploited fruits *viz.*, jamun, papaya and rose apple independently by varying the process parameters *viz.*, fruit: water ratio, fruit: sugar ratio, nitrogen source and clarification methods. Fruit: water ratio was tried at 1:1, 1:2 and 1.0.07; fruit: sugar ratio at 1:1, 24° brix and at 20% sugar, with or without nitrogen source and subjected to clarification by pectinase enzyme and by settling, thus forming 36 different wines under each fruit and were analysed for physical, chemical, nutritional and sensory quality parameters. The study was conducted as four continuous steps viz., fruit wine preparation, quality analysis, selection of superior wines and evaluation of storage stability.

Jamun wines were attractive dark purple, had good flavour with 71.8 to 95.4 per cent yield. Papaya wines were light yellowish, papaya flavoured and had 42.2 to 90.7 per cent yield. Rose apple wines were creamy white with 82.24 to 93.33 per cent yield.

Three wines with high yield, antioxidant activity and total sensory score with low alcohol content (<7%) were selected from each fruit.

Jamun wine prepared using 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, without nitrogen source and clarified by pectinase had 3.52% alcohol, 93.03% antioxidant activity and 253.29 mgg^{-1} polyphenol content with the highest total sensory score (18.5). When nitrogen source was added, the wine had highest (95.4%) yield, 3.52% alcohol content and high antioxidant activity (92.5%). The highest antioxidant activity (95.64%) was obtained for the wine produced using 1:2 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by pectinase. This wine had 92.8% yield, 5.85% alcohol content and 125.92mgg^{-1} polyphenol content.

Papaya wine produced with 1:1 fruit: water ratio, 1:1 fruit: sugar ratio, with nitrogen source and clarified by settling had 87% yield, 4.39% alcohol, 50.19mgg^{-1} polyphenol and 86.93% antioxidant activity. Addition of nitrogen source and

clarification by pectinase had resulted in wine with highest total mean sensory score (17), 3.52% alcohol, 83.65mgg^{-1} polyphenol and 86.54% antioxidant activity. Wine prepared with 1:2 fruit: water ratio, 1:1 fruit: sugar, with nitrogen source and clarified by pectinase had high yield (90.7%), 5.13% alcohol, 56.55mgg^{-1} polyphenol and 82.95% antioxidant activity.

Rose apple wine prepared with 1:1 fruit: water ratio, 1:1 fruit: sugar, without nitrogen source and clarified by settling had 92.33% yield, 3.52% alcohol, 112.34mgg^{-1} polyphenol and 75.12% antioxidant activity with highest total mean sensory score (16). Preparation of wine with 1:1 fruit: water ratio, 1:1 fruit: sugar, with nitrogen source and clarified by pectinase had resulted in wine with 91.33% yield, 3.52% alcohol, 151.65mgg^{-1}polyphenol and 80.13% antioxidant activity. The wine produced using 1:2 fruit: water ratio, 1:1 fruit; sugar ratio, without nitrogen source and clarified by settling had 93.33% yield, 4.39% alcohol, 108.66mgg^{-1} polyphenol, high antioxidant activity (83.33%) and highest total sensory score (16).

When the superior wines selected from each fruit were stored in amber coloured glass bottles and analysed for storage stability, it was seen that the polyphenol content decreased during storage. All the wines were microbiologically safe till the end of two moth storage.

In general, utilization of pectinase for clarification, addition of nitrogen source and clarification by pectinase or by doubling the water content in addition to nitrogen source and use of pectinase can improve yield, antioxidant property and sensory score of jamun wine. Addition of nitrogen source, use of pectinase and nitrogen source or doubling the water content with nitrogen source and use of pectinase can improve yield and sensory score of papaya wine. But alcohol content and antioxidant activity were significantly reduced by doubling water in addition to use of nitrogen source and pectinase. By doubling the water content or usage of a nitrogen source and pectinase enzyme, no significant improvement could be made in yield or alcohol content of rose apple wine; instead the antioxidant activity could be significantly improved.

The study clearly points out the relevance of selecting process parameters based on the quality of raw material used for wine making.

സംഗ്രഹം

വെള്ളായണി കാർഷിക കോളേജിലെ വിളവെടുപ്പാനന്തര സാങ്കേതിക വിദ്യാവിഭാഗത്തിൽ 2019-2021 കാലയളവിൽ 'വാണിജ്യവൽക്കരിക്കപ്പെടാത്ത പഴങ്ങളിൽ നിന്ന് ഗുണമേന്മയും സംഭരണ സ്ഥിരതയുമുള്ള വൈൻ ഉൽപ്പാദനത്തിനുള്ള സാങ്കേതിക വിദ്യ' ഉരുത്തിരിച്ചെടുക്കാനുള്ള പഠനങ്ങൾ നടന്നു. ഞാവൽ, പപ്പായ, ചാമ്പക്ക എന്നീ മൂന്ന് പഴങ്ങളിൽ നിന്നുമാണ് വീഞ്ഞ് തയ്യാറാക്കിയത്.

പഴച്ചാറും വെള്ളവും തമ്മിലെ അനുപാതം 1:1, 1:2, 1:0.07 എന്നിങ്ങനെയും, പഴച്ചാറും പഞ്ചസാരയും തമ്മിലെ അനുപാതം 1:1, 24°B, 20% എന്നിങ്ങനെയും നൈട്രജൻ സ്രോതസ്, തെളിയാനായി ഉപയോഗിക്കുന്ന രണ്ട് വ്യത്യസ്ത രീതികൾ എന്നിങ്ങനെ വിവിധ ഘടങ്ങളുപയോഗിച് 36 ഇനം വീഞ്ഞുകൾ ഓരോ പഴത്തിൽ നിന്നും ഉൽപാദിപ്പിച് അവയുടെ ഗുണനിലവാരം പരിശോധിക്കുകയുണ്ടായി. ഫ്രൂട്ട് വൈൻ തയ്യാറാക്കൽ, അവയുടെ ഗുണനിലവാര പരിശോധന, മികച്ച വൈനുകളുടെ തിരഞ്ഞെടുപ്പ്, സംഭരണ സ്ഥിരത വിലയിരുത്തൽ എന്നിങ്ങനെ തുടർച്ചയായ നാല് ഘട്ടങ്ങളായാണ് പഠനം നടത്തിയത്.

ഞാവൽ വൈനുകൾക്ക് ആകർഷകമായ ഇരുണ്ട പർപ്പിൾ നിറവും, നല്ല സ്വാദും 71.8 മുതൽ 95.4 ശതമാനം ഉല്പാദനവുമുണ്ടായിരുന്നു. പപ്പായ വൈനുകൾ ഇളം മഞ്ഞ കലർന്നതും പപ്പായയുടെ രുചിയുള്ളതും 42.2 മുതൽ 90.7 ശതമാനം വരെ ഉല്പാദനവും ഉണ്ടായിരുന്നു. ചാമ്പക്ക വൈനുകൾക്ക് 82.24 മുതൽ 93.33 ശതമാനം വരെ ഉല്പാദനവും ക്രീം വൈറ്റ് നിറവുമായിരുന്നു.

ഉയർന്ന ഉൽപാദനം, ആന്റിയോക്സിഡൻറ് ആക്ടിവിറ്റി, 7 ശതമാനത്തിൽ കുറഞ്ഞ ആൽക്കഹോൾ, ഉയർന്ന സെൻസറി സ്കോർ എന്നിവയെ അടിസ്ഥാനമാക്കി മൂന്ന് വൈനുകൾ ഓരോ പഴത്തിൽ നിന്നും തിരഞ്ഞെടുത്തു.

പഴച്ചാറും വെള്ളവും 1:1 അനുപാതത്തിലും പഴച്ചാറും പഞ്ചസാരയും 1:1 അനുപാതത്തിലും ഉപയോഗിച്ച് നൈട്രജൻ

സ്രോതസ് ഇല്ലാതെ, പെക്റ്റിനേസ് വഴി ക്ലാരിഫിക്കേഷൻ ചെയ്ത ഞാവൽ വൈനിൽ 3.52% ആൽക്കഹോൾ, 93.03% ആന്റിഓക്സിഡന്റ് ആക്ടിവിറ്റി, 253.29 mgg-1 പോളിഫിനോൾ, ഉയർന്ന സെൻസറി സ്കോർ (18.5) എന്നിവയുണ്ടായിരുന്നു. നൈട്രജൻ സ്രോതസ് ചേർത്തപ്പോൾ, വീഞ്ഞിന് ഏറ്റവും ഉയർന്ന (95.4%) ഉല്പാദനം ലഭ്യമായി. പഴച്ചാറും വെള്ളവും 1:2 എന്ന അനുപാതത്തിലാക്കുകയും നൈട്രജൻ സ്രോതസും പെക്റ്റിനേസും ഉപയോഗിക്കുകയും ചെയ്തപ്പോൾ വൈനിന് ഏറ്റവും ഉയർന്ന ആന്റിഓക്സിഡന്റ് ആക്ടിവിറ്റി (95.64%) ലഭിച്ചു. ഈ വീഞ്ഞിൽ 5.85% ആൽക്കഹോൾ, 125.92mg-1 പോളിഫിനോൾ എന്നിവ ഉണ്ടായിരുന്നു.

പഴച്ചാറും വെള്ളവും 1:1 അനുപാതത്തിലും പഴച്ചാറും പഞ്ചസാരയും 1:1 അനുപാതത്തിലും ഉപയോഗിച്ച് നൈട്രജൻ സ്രോതസ് ചേർത്ത് ഉൽപാദിപ്പിച്ച പപ്പായ വൈനിൽ 4.39% ആൽക്കഹോൾ, 50.19mgg-1 പോളിഫിനോൾ, 86.93% ആന്റിഓക്സിഡന്റ് ആക്ടിവിറ്റി എന്നിവ ഉണ്ടായിരുന്നു. നൈട്രജൻ സ്രോതസ്സും പെക്റ്റിനേസ് എൻസൈമും ഉപയോഗിച്ച് ഉണ്ടാക്കിയ വൈനിന് ഏറ്റവും ഉയർന്ന ശരാശരി സെൻസറി സ്കോർ (17), 3.52% ആൽക്കഹോൾ, 83.65mgg-1 പോളിഫിനോൾ, 86.54% ആന്റിഓക്സിഡന്റ് ആക്ടിവിറ്റി എന്നിവ ഉണ്ടായിരുന്നു. പഴച്ചാർ: വെള്ളം അനുപാതം 1:2, പഴച്ചാർ: പഞ്ചസാര അനുപാതം 1:1, നൈട്രജൻ സ്രോതസ്സും പെക്റ്റിനേസും ഉപയോഗിച്ച് ഉണ്ടാക്കിയ വൈനിൽ 5.13% ആൽക്കഹോൾ, 56.55mgg-1 പോളിഫിനോൾ, 82.95% ആന്റിഓക്സിഡന്റ് ആക്ടിവിറ്റി എന്നിവ ഉണ്ടായിരുന്നു.

1:1 പഴച്ചാർ: വെള്ളം, 1:1 പഴച്ചാർ: പഞ്ചസാര, നൈട്രജൻ സ്രോതസ്സില്ലാതെ തയ്യാറാക്കിയ ചാമ്പക്ക വൈനിന് ഏറ്റവും ഉയർന്ന സെൻസറി സ്കോർ (16), 92.33% ഉല്പാദനം, 3.52% ആൽക്കഹോൾ, 112.34mg-1 പോളിഫിനോൾ, 75.12% ആന്റിഓക്സിഡന്റ് ആക്ടിവിറ്റി എന്നിവ ഉണ്ടായിരുന്നു. 1:1 പഴച്ചാർ: വെള്ളം, 1:1 പഴച്ചാർ: പഞ്ചസാര, നൈട്രജൻ സ്രോതസ്, പെക്റ്റിനേസ് എന്നിവ ഉപയോഗിച്ച് തയ്യാറാക്കിയ വൈനിന് 91.33% ഉല്പാദനവും, 3.52% ആൽക്കഹോൾ,

151.65mg-1 പോളിഫിനോൾ, 80.13% ആന്റിഓക്സിഡന്റ് ആക്ടിവിറ്റി എന്നിവ ഉണ്ടായിരുന്നു. 1:2 പഴച്ചാർ: വെള്ളം അനുപാതം, 1:1 പഴച്ചാർ: പഞ്ചസാര, നൈട്രജൻ സ്രോതസ്സില്ലാതെ തയ്യാറാക്കിയ വൈനിൽ 93.33% ഉല്പാദനവും, 4.39% ആൽക്കഹോൾ, 108.66mgg-1 പോളിഫിനോൾ, ഉയർന്ന ആന്റിഓക്സിഡന്റ് ആക്ടിവിറ്റി (83.33%), ഉയർന്ന സെൻസറി സ്കോർ (16) എന്നിവയും ഉണ്ടായിരുന്നു.

ഓരോ പഴത്തിൽ നിന്നും തിരഞ്ഞെടുത്ത ഗുണമേന്മയുള്ള വൈനുകൾ വെളിച്ചംകടക്കാത്ത തവിട്ടു നിറമുള്ള ഗ്ലാസ് കുപ്പികളിൽ രണ്ട് മാസം സൂക്ഷിച്ച് സംഭരണ ശേഷി വിശകലനം ചെയ്തു. സംഭരണ സമയത്ത് പോളിഫിനോൾ കുറയുന്നതായി കണ്ടുവെങ്കിലും വൈനുകളെല്ലാം തന്നെ സൂക്ഷ്മാണു വിമുക്തമായിരുന്നു.

ചുരുക്കത്തിൽ ഗാർഹിക വൈൻ ഉല്പാദന രീതിക്ക് പകരം പെക്ടിനേസിന്റെ ഉപയോഗം അഥവാ നൈട്രജൻ സ്രോതസും പെക്ടിനേസും കൂടിയുള്ള ഉപയോഗം അഥവാ ഇവയ്ക്ക് ഒപ്പം വെള്ളത്തിന്റെ അളവ് ഇരട്ടിയാക്കൽ എന്നീ രീതികൾ വഴി ഞാവൽ വൈനിന്റെ ഉത്പാദനം, ആന്റിഓക്സിഡന്റ് ആക്ടിവിറ്റി, സെൻസറി ഗുണങ്ങൾ എന്നിവ വർദ്ധിപ്പിക്കാം എന്ന് കണ്ടു. നൈട്രജൻ സ്രോതസിന്റെ ഉപയോഗം, പെക്ടിനേസും നൈട്രജൻ സ്രോതസും ഉപയോഗിക്കുക അതുമല്ലെങ്കിൽ നൈട്രജൻ സ്രോതസിനും പെക്ടിനേസിനുമൊപ്പം ഇരട്ടി വെള്ളം ഉപയോഗിക്കുക എന്നിവ വഴി പപ്പായ വൈനിന്റെ ഉല്പാദനവും സെൻസറി സ്കോറും വർദ്ധിപ്പിക്കാം. എന്നാൽ നൈട്രജൻ സ്രോതസിന്റെയും പെക്ടിനേസ് എൻസൈമിന്റെയും ഉപയോഗമോ വെള്ളത്തിന്റെ അംശം ഇരട്ടിയാക്കുന്നതിലൂടെയോ ചാമ്പക്ക വൈൻ ഉല്പാദനത്തിലോ ആൽക്കഹോളിന്റെ അളവിലോ വർദ്ധനവുണ്ടായില്ല എങ്കിലും ആന്റിഓക്സിഡന്റ് ആക്ടിവിറ്റി വർദ്ധിപ്പിക്കാനായി.

വൈനിന്റെ ഗുണനിലവാരം തിരഞ്ഞെടുക്കുന്ന പഴങ്ങൾ ഉൾപ്പെടെ നാം ഉപയോഗിക്കുന്ന അസംസ്കൃതവസ്തുക്കളുടെ ഗുണമേന്മയെ അടിസ്ഥാനമാക്കി വ്യത്യസ്തമാകുന്നു എന്ന് ഈ പഠനം വ്യക്തമാകുന്നു.