International Journal of Home Economics, Hospitality and Allied Research, 1(2): 447-464.
DOI: https://doi.org/10.57012/ijhhr.v1n2.026
Received: August 26, 2022
Revised: November 30, 2022
Accepted: December 28, 2022
Published: December 31, 2022

Original Research Report

Production of Wine from Soursop Fruit Pulp for Entrepreneurship and Economic Sustainability in Rivers State, Nigeria

Sandra Owoh[1*]

[1]Ignatius Ajuru University of Education, Rumuolumeni, P.M.B 5047, Port Harcourt, Nigeria

***Correspondence:** Sandra Owoh, Ignatius Ajuru University of Education, Rumuolumeni, P.M.B 5047, Port Harcourt, Nigeria (Email: sandrawill2004.s@gmail.com)

Abstract: Abstract: The role of fruits in the human diet is well established due to various important nutritive and biologically active components intrinsic to fruits. Consequently, fruit wines tend to preserve these components, along with developing new desirable ones in the final product. Wine contains most of the nutrients present in the original fruit juice. The production of fruit wines is growing steadily in recent years, driven by the demand for new functional products. Soursop has a short shelf life under the prevailing temperature and humidity conditions. This results in to waste of fruits because of poor handling and inadequate storage facilities. Moreover, fermenting soursop juice into wine is considered an attractive means of utilizing surplus soursop. In this research, Table wine was successfully produced from soursop juice with an alcoholic content of 7%; physiochemical and sensory evaluation revealed the wine was of good quality after aging for three months. Results were comparable to a commercial wine used as a control.

Keywords: Nutrients, Physiochemical evaluation, Sensory evaluation, Soursop, Table wine

1. Introduction

According to Tamang and Samuel (2010), any fermented fruit juice can be referred to as wine. Commonly associated with grapes, wine can be produced using the nectar from most fruits as well as grains and plants. Also can be made from any material capable of growing yeast; this goes to prove that wine is more than just grapes. This process of active yeast growth on foodstuff is called alcoholic fermentation (Rivera-Espinoza; Valdez-López & Hernández-Sánchez, 2005). Many tropical and subtropical fruits, including plantain, grapes, apples, pears, apricots, berries, peaches, sugar cane, oranges, mangoes, bananas and pineapples yield good amounts of juice on extraction that can be used for wine making upon fermentation (Reddy & Reddy, 2005).

Wines are often central to the most valued personal and social ceremonies of both modern and less educated societies. Wines are often present in such traditional ceremonies as child naming, marriage feasts, and funerals. Swami, Thakor and Divate (2014) reported that wine is a distinctive product that influences major life events, from birth to death, victories, auspicious occasions, harvest, and other events, due to its analgesic, disinfectant, and profound mind-altering effects. Wines are healthful beverages that have been seen as a natural remedy for man's illness from early day and are said to aid recovery during convalescent period (Idise & Odum, 2011); wine contains most of the nutrients present in the original fruit juice. The nutritive value of wine is increased due to release of amino acids and other nutrients from yeast during fermentation.

Wines are classified as natural wines having an alcoholic content of 9-14%, dessert and appetizer wines with alcohol content 15-21%. Wine can also be categorized as sweet or dry depending on the conditions during alcoholic fermentation. The subjective sweetness of a wine is determined by the interaction of several factors, including not only the amount of sugar in the wine, but also the relative levels of alcohol, acids and tannins. In general, sugars and alcohol enhance a wine's sweetness while acids and tannins counteract it leading to a dry wine (Swami, et al., 2014). The most famous types of wines are red and white wines, followed by rosé and sparkling wines. Table wines are dry if sugar content is 0.3% and alcohol 9-14%, semi-dry with sugar content of 0.5-3% and alcohol 12.9% and sweet with sugar 3-8% and alcohol 12.9% (Ogodo, Ugbogu, & Ezeonu, 2015). Many volatile odorous compounds are found in wine. These aromatic substances are derived from three major sources: (1) the fruits, (2) Fermentation, (3) Aging and maturation.

Several factors are considered by winemakers during wine production. Prominent among such factors are the sugar content in the juice (must), the yeast strain used and the fermentation process (Reddy & Reddy, 2005). Making wine from other sources than grapes needs adjustments especially in the sugar level and acidity of the juice. Most fruits naturally either lack a high amount of fermentable sugars; have relatively low acid value, low yeast.

Soursop (Annona muricata L.) is a tropical fruit that belongs to the Annonaceae family having an exceptional aroma and flavour. It is an exotic fruit that is recognized for its very lovely, sub-acid, aromatic and juicy flesh (Minh, Nhi, Hue, Ha & Chien, 2019). The fruit pulp consists of white fibrous juicy segments surrounding an elongated receptacle (Nam, Park, Jang, & Rhee, 2017). Soursop fruit is an important source of vitamins, minerals and dietary fibre, the fruit and its juice are used to increase mother's milk (lactagogue) and as an astringent for diarrhea and dysentery (Coria-Tellez; Montalvo-González; Yahia, & Obledo-Vázquez, 2018). Juices produced from Soursop fruits pulp have increasingly gained global importance due to their characteristic unique flavour and colour. The fruit does not oxidize easily and there is a large recovery of pulp from the fruit during processing (Swami et al., 2014). In Europe soursop is sold as fresh or frozen pulp, strained soursop juice, and frozen

concentrates, which have been preserved as various juice blends, ice creams, syrups, jams, jellies, preserves, yoghurts, and ice creams.

Fermentations of fruit juice is a relative and simple avenue for reducing post-harvest wastage of mainly perishable fruits, hence perishable fruits can be used for production of wine (Govimath et al., 2013). Over the years, grape wine has dominated wine market, except in those areas where cultivation of grapes is limited by climatic conditions, in such areas continuous efforts have been made to produce wine by fermenting other fruit juice (Ogodo et al., 2015). To this effect, winemakers have moved beyond the vineyard to bottle fruit juice and every other thing that can ferment to give tasty products. Apart from varieties of fresh fruity flavours in fruit wine, each variety of fruit has its own unique blend of disease-fighting chemicals (Baiyeri, Aba, Otitoju, & Mbah, 2011). It has been reported that when fruits ferment and the sugars are removed, some key chemicals, like anthocyanins, become more active thereby improving the health benefits of the products. Strawberries, plums, watermelons, quince, apricot, apple, raspberries, bilberries, cherries blackberries, mango, sugar cane juice, peaches, gooseberries, boysenberries, grapefruits, pears, pineapples, persimmons are all very suitable for fruit home-made wine (Muhlack, Potumarthi, Jeffery, & David, 2018). Some well known fruit wines are hard Cider from apples, Perry from pears, Pomegranate wine, Banana, Plantain, Blueberry, Pumpkin and Elderberry wine (Okeke, Agu, Uba, Awah, Anaukwu, Archibong, Uwanta, Ezeneche, Ezenwa, & Orji, 2015).

Wines are classified as natural wines having an alcoholic content of 9-14%, dessert and appetizer wines with alcohol content 15-21%. Wine can also be categorized as sweet or dry depending on the conditions during alcoholic fermentation. The subjective sweetness of a wine is determined by the interaction of several factors, including not only the amount of sugar in the wine, but also the relative levels of alcohol, acids and tannins. In general, sugars and alcohol enhance a wine's sweetness while acids and tannins counteract it leading to a dry wine (Swami et al., 2014). The most famous types of wines are red and white wines, followed by rosé and sparkling wines. Table wines are dry if sugar content is 0.3% and alcohol 9-14%, semi-dry with sugar content of 0.5-3% and alcohol 12.9% and sweet with sugar 3-8% and alcohol 12.9% (Ogodo et al., 2015). Many volatile odorous compounds are found in wine. These aromatic substances are derived from three major sources: (1) Grapes (fruits), (2) Fermentation, (3) Aging and maturation.

Fermentations of fruit juice is a relative and simple avenue for reducing post-harvest wastage of mainly perishable fruits, hence perishable fruits can be used for production of wine (Gavimath, Kalsekar, Raorane, Kulkarni, Gavade, Ravishankar, & Hooli, 2012). Fermentation of food for preservation, enhancement of nutritive values and improvement of flavour and preparation of beverages has been practiced since prehistoric times by people of nearly every civilization (Baiyeri, et al., 2011). Different varieties of grapes and strains of yeasts produce different styles of wine.

Over the years, grape wine has dominated wine market, except in those areas where cultivation of grapes is limited by climatic conditions. In such areas, continuous efforts have been made to produce wine by fermenting other fruit juice (Ogodo et al., 2015). To this effect, winemakers have moved beyond the vineyard to bottle fruit juice and every other thing that can ferment to give tasty products. Apart from varieties of fresh fruity flavours in fruit wine, each variety of fruit has its own unique blend of disease-fighting chemicals. It has been reported that when fruits ferment and the sugars are removed, some key chemicals, like anthocyanins, become more active thereby improving the health benefits of the products. Strawberries, plums, watermelons, quince, apricot, apple, raspberries, bilberries, cherries blackberries, mango, sugar cane juice, peaches, gooseberries, boysenberries, grapefruits, pears,

pineapples, persimmons are all very suitable for fruit home-made wine (Muhlack et al., 2018). Some well known fruit wines are hard Cider from apples, Perry from pears, Pomegranate wine, Banana, Plantain, Blueberry, Pumpkin and Elderberry wine (Okeke et al., 2015). Several factors are considered by winemakers during wine production. Prominent among such factors are the sugar content in the juice (must), the yeast strain used and the fermentation process (Reddy & Reddy, 2005). Making wine from other sources than grapes needs adjustments especially in the sugar level and acidity of the juice. Most fruits naturally either lack a high amount of fermentable sugars; have relatively low acid value, low yeast.

Nigeria is not a wine producing country although few small to medium scale producers exist. Historically, local wines such as burukutu and palm wine have been in existence for ages before the modern commercial production of wine. Commercial wine production started with the processing of non-grape locally grown fruits like pawpaw and pineapples. Wine from these fruits offers a wide range of products from non-alcoholic to 10-15% alcohol content to suit the desires of a variety of consumers. Currently, the wines from the local wineries are not meeting the needs of the current consumers hence demands have shifted to foreign wine (Ogodo et al., 2015). There is a growing consumer demand for wine in Nigeria, the growth rate superseding that experienced in other alcoholic drinks categories.

One of the millennium development goals initiated by the Unites Nations in 2000 is to eradicate extreme poverty and hunger. Good Health and wellbeing, decent work and Economic Growth, Reduced Inequality and Responsible Consumption and Production. Idea of the Sustainable Development Goals is that people can achieve quality health and wellbeing, responsible consumption. Hence, entrepreneurship development enables a process of utilizing resources to produce new goods and services. Entrepreneur is a person who makes money by running a business which enables him/her to resolve many financial and social challenges. The potential of entrepreneurship as a possible solution to sustainable development challenges has been mentioned several times at the General Assembly of the UN. The resolution recognizes the role of entrepreneurship as a catalyst for development and to address sustainable development challenges – notably, unemployment, poverty and poor health – for all, including socially disadvantaged groups, women and youth (Muhlack et al., 2018). Soursop is sold and eaten fresh; there are no means of preservation or processing into other forms for future use. The fruit is grossly underutilized and unexploited in value addition. Evaluation of the post-harvest problems associated with tropical fruits especially with Soursop indicates that the post-harvest loss is extremely high hence; the aim of this study is production of wine from soursop fruit pulp as a means of reducing post-harvest loss for entrepreneurship and economic sustainability in Rivers State.

1.1. Statement of Problem

There is a growing consumer demand for wine in Nigeria, currently; the wines from the local wineries are not meeting the needs of the current consumers hence demands have shifted to foreign wine. Unlike other trees, planting of soursop is not regular only a few of not more than five trees can be seen in a whole settlement.

Soursop is sold and eaten fresh; there are no means of preservation or processing into other forms for future use. The fruit is grossly underutilized and unexploited in value addition.

Another problem is that the fruit is seasonal which makes it unavailable at off seasons thereby depriving people of its health benefits.

1.2. Purpose of the Study

The main purpose of the study is production of wine from Soursop fruit pulp for entrepreneurship in Rivers state. The specific objectives are to:

(a) Extract juice from soursop pulp and determine the physicochemical properties in terms of pH, specific gravity, total solids, total titratable acidity, brix°, turbidity etc.
(b) Produce wine from juice extracted from soursop pulp using saccharomyces cerevisiae and determine the physicochemical properties of the wine produced.
(c) Determine the mineral and vitamin content of juice extracted from soursop pulp such as potassium, calcium, magnesium, zinc, and the B vitamins.
(d) Carryout Organoleptic studies on the Soursop wine using 9-hedonic scale rating to evaluate appearance, taste, mouthfeel and general acceptability of the wine.

1.3. Research Questions

(a) What are the physicochemical properties in terms of pH, specific gravity, total solids, total titritable acidity, brix, turbidity?
(b) What are the Phytochemical Constituents in soursop wine using *saccharomyces cerevisiae?*
(c) What are the mineral and vitamin content of juice extracted from soursop pulp such as potassium, calcium, magnesium, zinc, and the B vitamins?
(d) What are the Mean Sensory Scores of Soursop Wine after Three Months Storage using 9-hedonic scale rating to evaluate appearance, taste, mouthfeel and general acceptability of the wine?

2. Materials and Methods

2.1. Design for the Study

The study made use of an experimental research design as described by Asouzu (2017).

2.1.1. Ethics Statement

Ethical permission was not requested from the ethics committee because it is not an animal/human study

2.2. Area of the Study

The area of study is Rivers State; Rivers State is one of the 36 states of Nigeria. According to census data released in 2006, the state has a population of 5,185,400, making it the sixth-most populous state in the country. Its capital, Port Harcourt is the largest city and is economically significant as the centre of Nigeria's oil industry (Mitee; Leesi Ebenezer, 2010). Rivers State is bounded on the South by the Atlantic Ocean, to the North by Imo, Abia and Anambra States; to the East by Akwa Ibom State, and to the West by Bayelsa and Delta states. The Ethnic composition, Languages, Culture and the Arts of Rivers State is diverse. These include Kalahari, lkwerre, Okrika, lbani (Bonny and Opobo) Ekpeye, Ogba, Etche, Khana, Gokana, Eleme, Ndoni, Abua, Odual.

2.3. Procurement of Raw Materials

Matured soursop fruit was purchased from fruit Garden, Mile 1 Rivers state. The fruit sample was sorted after which five kilogram (5kg) was weighed for the study. Yeast (saccharomyces cerevisiae), cheese cloth, wine jar were purchased from same source. Reagents/chemicals used were all of analytical grade, (BDH chemicals England) obtained from unique chemicals Ogbunabali Port Harcourt, Rivers State.

2.3. Processing of Sample

2.3.1. Juice Extraction

Five kilograms of "soursop" fruit was weighed washed, peeled, sliced and the seeds removed. The fruit was then blended with a sterile blender into puree, two hundred (200ml) millilitres of distilled water was first added to the blender to avoid friction and then another 300ml added during the extraction. The slurry was diluted in a ratio of 1:1 (water and pulp) blanched at 80℃ for 5minutes in a water bath and sieved with a muslin cloth to obtain the juice otherwise called "Must". The overall water added during the blending was 500ml.

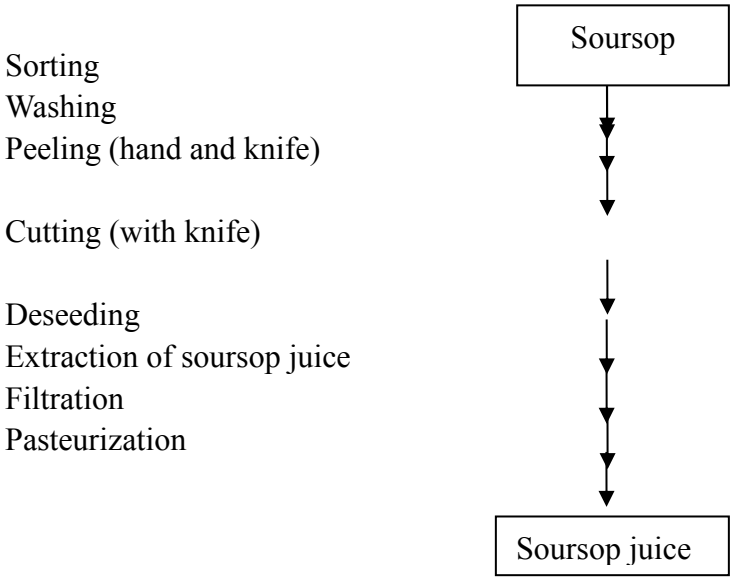

Figure 1. Extraction of Juice from soursop fruit pulp

2.4. Wine Production

2.4.1. Chaptalization and Supplementation of the "Must"

The method described by Kiin-Kabari & Barber (2019) was used with some modifications. The jar will be inoculated with 5% activated commercial yeast (*saccharomyces cerevisiae),* already dissolved in 150 ml distilled water to develop the inoculum was later poured into the fermenter jar containing 2150ml "must" making it a total of 2300ml. About 179.5g of sucrose was dissolved and added to the mixed juice (Chaptalization) to adjust the medium to 20°C Brix. The "must" was enriched with 6.72 g (0.84 g/L) of ammonium sulphate and 9.6 g (1.2g/L) of potassium dihydrogen phosphate to enhance the rapid growth of the fermenting yeast.

The inoculated "must" was covered with cotton wool and incubated at room temperature. The fermenting "must" was aerated daily by shaking to encourage yeast multiplication. Aerobic fermentation was terminated after 7 days. During this period, microbial analysis, alcohol, sugar content, specific gravity, titratable acidity and pH was monitored at two-day intervals. At the end of fermentation, finally, the juice was pasteurized at 78°C for 30min).

2.4.2. Clarification and Racking

After fermentation and pasteurization, the wine was racked to clarification.

2.4.3. Aging

After the racking, the wine was kept in the refrigerator for maturation (2 weeks) and then packaged for further analysis. The upper liquid was transfer to another clean container in order to remove

impurities. The sample was allowed to age at 20°C for 4 weeks before analysis.

2.4.4. Wine Stabilization and Filtration

Following complete fermentation, the soursop wine was stabilized and filtered through 0.3µm filter pads and treated with citric acid before analysis.

2.5. Physical Properties Soursop Wine

During Fermentation, aliquot sample was removed daily from the fermentation tank for analysis of the followings:

2.5.1. Test for pH

pH of the wine sample was measured using a pre-calibrated digital pH meter (Hanna pH 211 microprocessor pH meter). Before reading pH, each sample was agitated (using a magnetic stirrer) for 30 s until a stable reading is measured. Between readings, the electrode was rinsed with distilled water for the accuracy of the measurement. Test was made in triplicate as described by Ogodo et al. (2015).

2.5.2. Alcohol Content

The alcohol content of the wine was determined using specific gravity as described by Okeke et al., 2015) and calculated as follows:

$$\text{Percentage alcohol} = \frac{(\text{OG} - \text{FG})\ 1.05}{0.8} \times 100$$

Where:

OG = Original Gravity of the sample;
FG = Final Gravity of the sample;
1.05 = grams of ethanol per gram of CO_2 released;
0.8 = density of ethanol.

2.5.3. Measurement of Temperature

The periodic temperature change during fermentation was recorded using 100^0C mercury in bulb thermometer that was inserted in the fermentation flask through a sterile rubber cork.

2.5.4. Determination of Specific Gravity

Method described by AOAC, (2019) was followed; the specific gravity was determined using a 50ml pychonometer. The bottle (50ml) was cleaned with distilled water, dried in an oven and cooled. The dried empty bottle was weighed and the value recorded as W_1. Then the bottle was filled with distilled water and weighed, recorded as W2. Again, the bottle was dried and filled with the wine sample, weighed and recorded as W3. The specific gravity of the sample was calculated as shown below;

$$\text{Specific gravity} = \frac{w3-w1}{w2-w1}$$

Where,

W1 = weight of empty pychonometer
W2 = weight of distilled water
W3 = weight of wine sample

2.5.5. Determination of Turbidity

To the Hack turbidimeter cell, the wine sample was added to a horizontal mark. After closing the cell, it was wiped using a tissue and placed in the turbidometer (Hach, Model 2100 N, Hach Company, Loveland, CO, USA). The turbidity value was assessed when the reading becomes stable. The turbidity of the juice before fermentation was measured also in Nephelometric Turbidity Units (NTU) and also in freshly extracted juices.

2.5.6. Determination of Total Dissolved Solids (TDS)

A crucible was dried in an air oven at 105℃ for one hour. Then it will be placed in a desiccator for one hour and allowed to cool and weighed (W1). 20 ml of the sample will be filtered by using filter paper into the weighted crucible W2. The crucible containing the filtrate was dried in the oven for one hour. At the end of one hour the crucibles was placed in desiccators and allow cooling. Finally, the crucible containing the dried sample was weighed W3 and total dissolved solids calculated using the formula below.

$$\text{Total Dissolved Solids (TDS)} = \frac{W3 - w1}{W2 - W1} \times 100$$

Where,

W1 = weight of empty crucible

W2 = weight of weight of sample and crucible

W3 = weight of dried sample

2.5.7. Determination of Total Titratable Acidity (TTA)

The percent titratable acidity (TTA) was determined following the method described by Othman, (2011). Ten millimetres (10ml) of the sample was poured in beaker and allowed to stand for 10 minutes. The solution was filtered with Whatman filter paper (Grade 1, Qualitative Filter Paper, Standard Grade, 25mm).

Twenty five milliliters of the filtrate was titrated against 0.1 M NaOH using phenolphthalein as indicator. The acid was expressed as % lactic acid. The mean of TTA was obtained from triplicate determinations and calculated as follows:

$$\text{TTA (\%)} = \frac{\text{Average titre value} \times 0.1\text{M} \times 0.009008)}{\text{Weight of sample} \times 100}$$

2.6. Quantification of Phytochemicals

As described by AOAC, (2019) official method of analysis, Phytate, Tannin, Flavonoids, and Total Phenolic Content was determined.

2.6.1. Determination of Phytate

Twenty-five milliliters of the filtrate was placed in a 100 mL conical flask and 5mL of 0.03% (w/v) NH_4 SCN solution added as indicator. Distilled water (50 mL) was added to give it a proper acidity. This was titrated against ferric chloride solution which contained about 0.005 mg of Fe2+ per $FeCl_3$ was used, the equivalent was obtained and from this, the phytate content in mg/100 was calculated.

Iron equivalent = titre value × 1.95

:. Phytic acid = titre value × 1.95 × 1.19 × 3.55 mg/phytic acid = 8.24

:. % phytic acid = (α × 8.24) /1000 × 100 / (weight of sample)

Where α = titre value.

2.6.2. Determination of Tannin

Fifty milliliters of each sample was poured into a sample bottle. Ten milliliters of 70% (v/v) aqueous acetone was added and properly covered. The bottles was put in an ice bath shaker and shaken for 2 hours at 30°C. Each solution was then centrifuged and the supernatant stored on ice. Each solution (0.2mL) was pipetted into a test tube and 0.8mL of distilled water added. Standard tannic acid solution was prepared from a 0.5mg/ml stock and the solution made up to 1mL with distilled water. A Folin reagent (0.5mL) will be added to the test sample and the standards prepared followed by addition of

2.5mL of 20% (w/v) Na_2CO_3. These solutions were then vortexed and incubated for 40minutes at room temperature of 28°C ± 2°C). The absorbance was read at 725nm against the reagent blank concentration of the sample. From the optical density of the tannic acid, standard curve was plotted. The tannin content of the samples was obtained from the standard curve.

2.6.3. Determination of Flavonoid

The flavonoid content in the produced wine was determined utilizing spectrophotometric method Quettier-Deleu (2000). The sample (20uL) was added to 2mL of 2% $AlCl_3$ solution dissolved in methanol. The sample was incubated for 1 h at room temperature (25℃). The absorbance was assessed using the spectrophotometer at *l*max = 415 nm. The same step was repeated for the standard solution of rutin, and the calibration line was built. Based on the determined absorbance, the concentration of flavonoids was read (mg/mL) on the calibration curve; and the flavonoid contents of must and wine was expressed in rutin equivalents (g rutin/g of extract).

2.6.4. Determination of Total Phenol Content

Ten milliliters of diluted sample was added to 2.5mL of 10% (v/v) Folin–Ciocalteu reagent was added, followed by the addition of 2mL 7.5% (w/v) Na_2CO_3, then mixed well on a vortex vibrator for 5minutes and incubated in the dark at ambient temperature (29°C) for 1 h prior to measuring the absorbance at 765 nm. Gallic acid was used as a calibration curve and the results expressed as mg gallic acid equivalents per 100mL sample.

2.7. Mineral Composition

As described by AOAC, (2019) official method of analysis, Potassium, calcium, zinc, iron, sodium, contents was determined using Atomic Absorption Spectrophotometer (Thermo scientific S series Model GE 712354) after digestion with a perchloric-nitric acid mixture. Phosphorus content was determined by Vanado molybdate method using spectrophotometer. Prior to digestion, 10ml of each sample will be measured into 125mL Erlenmeyer flask with the addition of perchloric acid (4mL), concentrated HNO_3 (25mL) and concentrated H_2SO_4 acid (2mL) under a fume hood. The contents were mixed and heated gently on a hot plate in a digester at low temperature to medium heat under perchloric acid fume hood and heating continued until dense white fume appeared. It was allowed to cool followed by the addition of distilled water (50mL). The solution was filtered completely and washed into a Pyrex volumetric flask and was made up with distilled water. Absorbance of the solution was read in Atomic Absorption Spectrophotometer in triplicate.

2.8. Sensory Evaluation

Four sensory attributes of the soursop wine were appraised by an untrained sensory panel of five persons in terms of appearance, taste, aroma, color and overall acceptability). An appropriate point value was assigned to individual attributes using a 9-point hedonic scale where 9 indicate extremely like and 1 extremely dislike.

2.9. Data Analysis Technique

Data from the laboratory analysis was subjected to analysis of variance (ANOVA) where the difference between means was separated using Turkey's multiple comparison range tests, and significance accepted at $P < 0.05$ level. The statistical package in MINITAB 16 computer package was used.

3. Results and Discussion

The data from laboratory analysis on wine produced from soursop fruit pulp for entrepreneurship and economic sustainability in Rivers State is presented in this chapter with the aid of tables and percentages.

3.1. Research question one: What are the physicochemical properties in terms of pH, specific gravity, total solids, total titritable acidity, brix, turbidity?

Table 1. Physical Properties of Soursourp Wine

No of Weeks after fermentation	pH	Specific gravity	TTA g/L	TDS %	Turbidity NTU	A/L% content	Sugar content
1	6.52^{a} ±0.010	1.42^{a} ±0.011	1.01^{c} ±0.00	14.22^{a} ±0.01	8.66^{a} ±0.57	2.41^{d} ±0.01	12.33^{a} ±0.57
2	4.41^{b} ±0.007	1.40^{a} ±0.01	1.01^{c} ±0.00	13.32^{b} ±0.01	8.03^{ab} ±0.05	2.85^{c} ±0.05	9.66^{b} ±0.57
3	3.89^{b} ±0.01	1.21^{a} ±0.05	1.22^{b} ±0.01	13.26^{c} ±0.02	7.10^{b} ±0.10	4.46^{b} ±0.05	6.66^{c} ±0.57
4	3.32^{c} ±0.015	1.09^{a} ±0.05	3.83^{a} ±0.01	1.58^{d} ±0.01	1.66^{c} ±0.57	$7.48a^{b}$ ± 0.00	1.60^{d} ±0.57
Commercial wine	3.54^{a} ±0.010	1.02^{d} ±0.01	4.2^{b} ±0.57	1.17^{f} ±0.01	1.18^{d} ±0.01	12.5^{a} ±0.01	1.12^{c} ±0.01

Means in the same column with different superscripts are significantly different ($P<0.05$)

Key:

TTA= Total Titrable Acidity

TDS = Total Dissolved Solutes

NTU = Nephelometric Turbidity Units

A/L = Alcohol Content

pH of the wine reduced after one week from 6.52 to 3.32. This agrees with the findings of Idise and Odum (2011) who noted that it is due to acid production by microorganism during fermentation. Okeke et al. (2015) also observed same decrease in their study on mixed fruits (pineapple and watermelon). A decrease in pH and an increase in acidity during production of mixed fruit wines of pawpaw, banana and watermelon were also reported by Ogodo et al. (2015).

The specific gravity of the soursop wine after four weeks was 1.09. According to Uraih (2003) & Okafor (2007), specific gravity of wine decreased due to microbial utilization of nutrients primarily sugars in the juice for metabolic activities with the evolution of CO_2 and heat. During fermentation, the changes in specific gravity of the wine decreased from the week one to week four. Specific gravity of the commercial wine used as control sample remained 1.02.

Total titratable Acidity defines the structure and balance of wine; it is dependent on the concentration of acids such as tartaric and malic acids and to a lesser extent on the concentration of lactic and acetic acid (Lima et al., 2010; Rizzon et al. 2000) reported that the skin of the Isabella grape

yields a higher concentration of organic acids than that of *Vitis vinifera* cultivars, possibly due to release of the skin's organic acids during maceration.

However, (Balogun et al. 2017) in their research on physicochemical and sensory properties of blends of pineapple-carrot wine, observed a steady decrease in titratable acidity with time throughout the period of primary fermentation and then increased slightly during the 30 days aging period. There were significant differences ($p<0.05$) in all the samples throughout fermentation periods. Studies have also shown that during fermentation of fruits, low pH and high acidity are known to give fermenting yeasts competitive advantage in natural environments (Idise & Odum, 2011). Acidity plays a vital role in determining wine quality by aiding the fermentation process and enhancing the overall characteristics and balance of the wine. Lack of acidity will result to the production of a poor fermentation process (Berry, 2000).

For the total soluble solids, a decrease was observed. The total dissolved solid content was 14.22% and 1.17% in the commercial wine sample used as control. The addition of water during the extraction process contributed to the increase in extraction yield because at the fixed temperature, the starch granules were not gelatinized, and therefore, the more water was added during the process, the more it was recovered during centrifugation to obtain the juice; while, at the same time, the increase of water when proceeding to extraction contributed to diluting the total soluble solids of that juice, which had as the impact the reduction of the concentration (in percentage) of total soluble solids in the juice. The reduction in total soluble solids was also due to the assimilation of the sugars by the yeast (Ukwuru & Awah, 2013). This reduction of TSS during the fermentation was again observed in the analysis of pineapple wine conducted by (Chanprasartsuk et al., 2012).

The results on turbidity showed a decreased from 8.66 to 1.66 NTU. The high turbidity observed in the first week could be due to the fact that the yeast metabolized the sugars, and that produced a high volume of CO_2 (Wilson et al., 2003). Gas escaping created turbulence in the medium and dispersing yeast and the progressive reduction of turbidity could be linked to the reduction of CO_2 production and, at the same time, the beginning of yeast and other solids' decantation. The higher the turbidity, the more sediment is present. The optimum range for lack of turbidity is 0.1-0 NTU. Result obtained for the commercial wine used as control sample was 1.18 NTU. When judging wine, the consumer has two areas of visual evaluation: clarity and colour. The clarity of the wine is expected to be crystal clear. Any type of cloudiness or sediment that can be seen in the wine disappoints the individual and hints to possible contamination as well as poor processing (Waters et al., 2005).

The alcohol content of the wine after four weeks was 7.48% (w/v). There was significant differences ($p<0.05$) between alcohol content of the soursop wine and the commercial wine used as control sample. The percentage alcohol produced from the fruits used for the fermentation by the yeast strain was low which is not comparable with moderate grape wines (Okunowo et al., 2005). Alcoholic content in the commercial wine sample was 12.55%. High alcohols are known to be important precursors for the formation of esters, which are associated with pleasant aromas also owing to their physiological and chemical composition of fruit varieties. Reddy and Reddy (2005) reported that the concentration of ethanol contributes to the whole characteristics quality and flavour of produced wine.

Sugar content of the final soursop wine was 1.60% while the imported wine had sugar content of 1.12%. Inadequate sugar content and low level of acidity have been reported as the major problems associated with making non-grape wine Ogodo et al. (2015). The result from this research agreed with the reports of (Ogundele et al., 2016) who observed a decrease in the sugar content of overripe mango wine sugar decreased from 1.3-3.0%.

3.2. Research question two: What are the Phytochemical Constituents in soursop wine using *saccharomyces cerevisiae?*

Table 2. Phytochemical Constituents in soursop wine

Phytochemical (mg/l)	**Soursop wine**	**Commercial wine**
Tannin	0.36^{a} ±0.01	0.34^{b} ± 0.01
Flavonoids	0.17^{a} ±0.01	0.10^{b} ± 0.01
Total Phenol	0.24^{b} ± 0.01	0.38^{a} ±0.01

Means in the same column with different superscripts are significantly different (P<0.05)

There was no significant (P<0.05) difference in the Tannin content of soursop and commercial wine. The findings of Mercurio et al. (2008) revealed that aged wine has similar concentration of tannin as young wine. During processing and in aging, the tannin content in the wine polymerized, Polymerization leads to increased molecular size. As the molecular size increases the astringency is perceived more than bitterness.

Tannins (commonly referred to as tannic acid) are water-soluble polyphenols that are present in many plant foods. They have been reported to be responsible for decreases in feed intake, growth rate, feed efficiency, net metabolizable energy, and protein digestibility in experimental animals. Therefore, foods rich in tannins are considered to be of low nutritional value (Kumar, Reddy & Varakumar, 2010). However, recent findings indicate that the major effect of tannins was not due to their inhibition on food consumption or digestion but rather the decreased efficiency in converting the absorbed nutrients to new body substances. Incidences of certain cancers, such as esophageal cancer, have been reported to be related to consumption of tannins-rich foods such as betel nuts and herbal teas, suggesting that tannins might be carcinogenic. However, other reports indicated that the carcinogenic activity of tannins might be related to components associated with tannins rather than tannins themselves. Interestingly, many reports indicated negative association between tea consumption and incidences of cancers. Tea polyphenols and many tannin components were suggested to be anti-carcinogenic. Many tannin molecules have also been shown to reduce the mutagenic activity of a number of mutagens (Lan *et al.*, 2017).

Flavonoids are the most common bioactive compounds found in medicinal plants (Patil & Shanmugasundaram, 2015).They have several preventive activities in human disease such as antimicrobial, antioxidant, anticancer, Anticarcinogenic flavonoids anti-inflammatory (the active flavonoids, quercetin and rutin another flavonone) and wound-healing capacity (Chirumbolo, 2012). As secondary metabolites, Flavonoids, a pigment that colour most flowers, fruits, and seeds are widely distributed in plants with different metabolic functions. These polyphenolic compounds are ubiquitous group characterized by the flavan nucleus and available as a group of bioactive compounds in fruits, vegetables and plant-derived beverages (Buer, Imin, & Djordjevic 2010). Daily intakes of flavonoids reduce risk of verity of chronic diseases, including cancer, cardiovascular disease (CVD) and neurodegenerative disorders. Anthocyanins are the flavonoid constituents abundant in cell vacuole

responsible for pigmentation in flowers, fruits, and vegetables and produced generally during plant under environmental stress (USDA, 2014).

The Total Phenol content of commercial wine was more when compared to soursop wine. Results were 0.38 and 0.24 % respectively. Nwaichi et al (2017) reported that aging could increase the phenolic compounds in wine. The activity of microorganisms during alcoholic fermentation also enhances the phenolic compounds in wine. These phenolic compounds are responsible for the taste and other sensory characters. Popa et al., (2018) proved that there is positive relationship between phenolic compounds and antioxidant activity of wine. According to the available literature, organically produced fruits may contain higher levels of phenolic compounds. Phenolics represent endogenous defence substances of plants that are more intensively synthesized (as a part of plant defense mechanisms) in the absence of synthetic pesticides and fertilizers commonly used in the conventional production system.

3.3. Research question three: What are the mineral and vitamin content of juice extracted from soursop pulp such as potassium, calcium, magnesium, zinc, and the B vitamins?

Table 3. Mineral Content in soursop and Commercial Wine

Parameters (mg/l)	**soursop wines**	**Commercial wine**
K+	$40.66^{b} \pm 1.528$	$34.00^{a} \pm 1.000$
Ca ++	$8.00^{a} \pm 1.000$	$7.66^{a} \pm 0.577$
Mg ++	$27.00^{b} \pm 1.000$	$33.00^{a} \pm 1.000$
Mn	$4.54^{a} \pm 0.010$	$2.43^{b} \pm 0.010$

Means in the same column with different superscripts are significantly different ($P<0.05$)

Key:

K+ = Potassium

Ca ++ = Calcium

Mg ++ =Magnesium

Mn =Manganese

Result of the Mineral Composition of the soursop wine is presented in table 3. Values obtained showed that Potassium, Calcium, Magnesium and Manganese in soursop wine were higher than the value obtained for the control sample. Potassium is essential for normal growth and sustaining life. It regulates cell growth (Niemeyer 2001) and maintains normal blood pressure (Adebayo et al., 2014). Calcium is essential for bone formation, strong teeth development and digestion aids enzyme stabilizers as well as transport co-factors in metabolic pathway. Aging wine increase calcium content when compared to fresh wine.

Magnesium is a multi-functioning mineral that makes large contribution to health and nutrition. The consumption of wine rich in Magnesium regulates potassium channel in the myocardial cells (Laires et al 2004). Manganese contributes to both enzyme activation as well as enzyme productivity. It supports the skeletal frame, eliminates free radicals and aids in healing wounds. Manganese in fresh wine is always more than aging wine. Soursop wine gave a value of 4.54 mg/100ml while the commercial wine gave a value of 2.43mg/100ml.

3.4. Research question four: What are the Mean Sensory Scores of Soursop Wine after Three Months Storage using 9-hedonic scale rating to evaluate appearance, taste, mouthfeel and general acceptability of the wine?

Table 4. Mean Sensory Scores of Soursop Wine after Three Months Storage

Samples	Month	Appearance/ Clarity	Taste	Aroma	Overall acceptability
	0	$5.90^{b}\pm0.100$	$6.91^{b}\pm0.081$	$8.84^{a}\pm0.459$	$8.71^{b}\pm0.217$
	1	$6.41^{b}\pm0.071$	$7.22^{b}\pm0.081$	$8.84^{b}\pm0.217$	$8.82^{c}\pm0.100$
Soursop wine	2	$7.22^{a}\pm0.100$	$7.77^{c}\pm0.100$	$8.97^{a}\pm0.331$	$8.84^{b}\pm0.217$
	3	$7.48^{c}\pm0.331$	$8.04^{b}\pm0.459$	$8.97^{a}\pm0.331$	$8.87^{b}\pm0.217$
Commercial wine	-	$9.05^{a}\pm0.020$	$5.50^{b}\pm0.000$	$8.58^{a}\pm0.010$	$8.84^{a}\pm0.010$

Means in the same column with different superscripts are significantly different ($P<0.05$)

Hedonic scale

9=like extremely, 8=like very much, 7=like moderately,6=like slightly,5=neither like nor dislike 4=like slightly, 3=dislike moderately, 2=dislike very much, 1=dislike slightly.

The responses of the panelists in the Sensory Evaluation of the soursop wine and the commercial wine used as control sample are presented in Table 4. Mean Sensory Scores by respondents for soursop wine was impressive. The result showed that there was significant difference ($p<0.05$) between soursop wine and the commercial wine in some of the parameters tested. However, there was no significant difference ($p<0.05$) in the results when compared with other tropical fruit wine reported by other researchers such as mixed fruit wine from pawpaw, banana and watermelon (Ogodo et al., 2015), banana wine (Akubor et al.,2003) sweet potato wine (Ray et al.,2012). According to the panelists, soursop wine exhibited more turbidity than in commercial wine. Turbidity could be due to the greater presence of solids in the "must". Consumers prefer crystal clear wine. However, most panellists believe that the turbidity could mean more nutrients in the wine (different opinions), hence higher scores for soursop wine.

Taste attribute was relative; soursop wine was more astringent, mean scores for taste ranged between 6.91 (76.66%) and 8.58 (95.33%) in the soursop wine and the commercial wine respectively. The commercial wine was perceived as the sweetest while the soursop wine produced the least sweet juice. It was perceived as the most acidic. However, some persons do not like sweet wines. Sweetness of wines depends on the amount of residual sugar present in wine; Phenolic compounds, especially flavan-3-ol polymers, as well as organic acids, contribute to the astringency of wine. In terms of Overall acceptability the commercial wine was preferred for its clarity over the soursop wine; however, the panelist gave higher scores to the soursop wine for aroma and taste.

4. Conclusion

Table wine was successfully produced from soursop juice with alcoholic content of 7%; physiochemical and the sensory evaluation revealed the wine was of good quality after aging for three months. Results were comparable to a commercial wine used a control. The nutritive value of wine is increased due to release of amino acids and other nutrients from yeast during fermentation. The consumption of soursop wine will provide a rich source of phytonutrients, minerals and vitamins and harness the fruits into a useful product in terms of value addition. It is therefore recommended that consumption of soursop juice or wine should be encouraged and planting of soursop tree should also be encouraged.

Acknowledgements

The author is grateful to Ignatius Ajuru University of Education, Rumuolumeni, Port Harcourt, Nigeria and also to the good people of Kalahari, lkwerre, Okrika, lbani (Bonny and Opobo) Ekpeye, Ogba, Etche, Khana, Gokana, Eleme, Ndoni, Abua, Odual for their support during the research work.

Conflict of Interest

The author declare that there is no conflict of interest.

Author Contributions

Conceptualization: SO.
Funding acquisition: SO,
Methodology: SO,
Data analysis: SO,
Writing – original draft, review & editing: SO.

Data Availability Statement

The original contributions presented in the study are included in the article. Further enquiries can be directed to the corresponding author.

Funding Information

The author has no funding to disclose.

References

Adebayo, B. A., Gabriel, N.P, Bamidele, A., Nicholas, M. & Mateete, B. (2014). Postharvest food losses in a maize-based farming system of semi-arid savannah area of Tanzania. *Journal of Stored Products Research, 57*, 49-57. https://doi.org/10.1016/j.jspr.2013.12.004

Akubor, P. I., Obio, S. O., Nwadomere, K. A., & Obiomah, E. (2003). Production and quality evaluation of banana wine. *Plant Foods for Human Nutrition*, *58*, 1-6. https://doi.org/10.1023/B:QUAL.0000041138.29467.b6

AOAC (2019). Official Methods of Analysis of the Association of Official Analytical Chemists: Official Methods of Analysis of AOAC International, 21st Edition, Washington D.C. (USA).

Archibong, E.J., Ezemba, C. C., Chukwujama, I. C. & Archibong, U. E., (2015). Production of wine from mixed fruits: pineapple (Ananas comosus) and orange (Citrus sinensis) using yeast isolated from palm wine. *World Journal of Pharmacy and Pharmaceutical Sciences*, *4*, 126-

136.

Asouzu, A. I. (2017). *Fundamentals of Research Methods in Home Economics*. Port Harcourt: Pearl Publishers International Ltd.

Baiyeri, K. P., Aba, S. C., Otitoju, G. T., & Mbah, O. B. (2011). The effects of ripening and cooking method on mineral and proximate composition of plantain (Musa sp. AAB cv.'Agbagba') fruit pulp. *African Journal of Biotechnology*, *10*, 6979-6984.

Balogun, T. V., Abdulkadir, A., Ikegwu, M. T., Akpadolu, B., & Akpadolu, K. (2016). *Production and Sensory Evaluation of Non-alcoholic Wine from Sugarcane and Tiger nut blend using saccharomyces cerevisia.* John Wiley.

Berry, L. L. (2000). Cultivating service brand equity. *Journal of the Academy of marketing Science*, *28*, 128-137. https://doi.org/10.1177/0092070300281012

Buer, C. S., Imin, N., & Djordjevic, M. A. (2010). Flavonoids: new roles for old molecules. *Journal of Integrative Plant Biology*, *52*, 98-111. https://doi.org/10.1111/j.1744-7909.2010.00905.x

Chanprasartsuk, O., Pheanudomkitlert, K., & Toonwai, D. (2012). Pineapple wine fermentation with yeasts isolated from fruit as single and mixed starter cultures. *Asian Journal of Food and Agro-Industry*, *5*, 104-111.

Chirumbolo, S. (2005). Flavonoids in propolis acting on mast cell-mediated wound healing. *Inflammopharmacology*, *20,* 99-102. https://doi.org/10.1007/s10787-012-0125-9

Coria-Tellez, A.V., Montalvo-González, E., Yahia, E.M. & Obledo-Vázquez, E.N (2018). Annona muricata: A comprehensive review on its traditional medicinal uses, phytochemicals, pharmacological activities, mechanisms of action and toxicity. *Arabian Journal of Chemistry*. 11, 662–691. https://doi.org/10.1016/j.arabjc.2016.01.004

Gavimath, C. C., Kalsekar, D. P., Raorane, C. J., Kulkarni, S. M., Gavade, B. G., Ravishankar, B. E., & Hooli, V. R. (2012). Comparative analysis of wine from different fruits. *International Journal of Advanced Biotechnology and Research*, *3*, 810-813.

Idise & Odum, (2011). Studies of wine produced from banana (Musa Sapientum*). International Journal for Biotechnology and Molecular Biology Research*, *2*, 209-214. https://doi.org/10.5897/IJBMBR11.033

Kiin-Kabari, D. B., Igbo, Q., & Barber, L. I. (2019). Production and evaluation of table wine using two different varieties of pawpaw (Carica papaya). *Journal of Food Science and Engineering*, *9*, 199-209. https://doi.org/10.17265/2159-5828/2019.06.002

Lan, Y., Wu, J., Wang, X., Sun, X., Hackman, R.M, Li, Z. & Feng, X. (2017). Evaluation of antioxidant capacity and flavor profile change of pomegranate wine during fermentation and aging process. *Journal of Food Chemistry*, *232*, 777-787. https://doi.org/10.1016/j.foodchem.2017.04.030

Laires, M.J., Monteiro, C.P. & Bicho, M. (2004). *Role of cellular magnesium in health and human disease. Frontiers in Bioscience, 9,* 262-276. https://doi.org/10.2741/1223

Lima, L. L. A., Schuler, A., Guerra, N. B., Pereira, G. E., Lima, T. L. A., & Rocha, H. (2010). Otimização e validação de método para determinação de ácidos orgânicos vinhos por cromatografia líquida de alta eficiência. *Quimica Nova*, *33*, 186-1189. https://doi.org/10.1590/S0100-40422010000500032

Minh NP, Nhi TTY, Hue DN, Ha DTT & Chien VM (2019) Quality and Shelf Life of Processed Pineapple by Different Edible Coatings. *Journal of Pharmaceutical Sciences and Research 11*, 1441-1446.

Mercurio, M.D & Smith P.A (2008). 'Tannin quantification in red grapes and wine:comparison of polysaccharide and protein based tannin precipitation techniques and their ability to model wine astringency. *Journal of Agricultural and Food Chemistry, 56,* 5528-5537. https://doi.org/10.1021/jf8008266

Muhlack, R. A., Potumarthi, R., Jeffery, J. & David, W. (2018). *Sustainable wineries through waste valorisation: A review of grape marc utilization for value-added products. WasteManagement, 72, 99–118.* https://doi.org/10.1016/j.wasman.2017.11.011

Nam, J.S., Park, S.Y., Jang, H.L. & Rhee, Y.H. (2017). Phenolic compounds in different parts of young *Annona muricata* cultivated in Korea and their antioxidant activity. *Applied Biological Chemistry*, *60*, 535–543. https://doi.org/10.1007/s13765-017-0309-5

Niemeyer, M.I., Cid, L.P., Barros, F. & Sepulveda, F.V. (2001). Modulation of the two – Pore domain acid – sensitive K+ Channel' TASK – 2 (KCHNK5) by changes in cell volume. *Journal Biology Chemistry, 276*, 43166-43174. https://doi.org/10.1074/jbc.M107192200

Nwaichi, E.O., Osuoha, J.O. & Monanu, M.O., (2017), Nutraceutical potential of *Tetracarpidiumconophorum* and *Buccholziacoriacea* indiet-induced hyperlipidemia. *Journal of Chemical Health Risks, 7*, 157–170.

Ogodo, A.C., Ugbogu, O.C., Ugbogu, A.E. and Ezeonu, C.S. (2015). Production of mixed fruit (pawpaw, banana and watermelon) wine using *Saccharomyces cerevisiae* isolated from palm wine. *SpringerPlus, 4,* 683. https://doi.org/10.1186/s40064-015-1475-8

Ogundele, L. T., Owoade, O. K., Olise, F. S., & Hopke, P. K. (2016). Source identification and apportionment of PM2. 5 and PM2. 5− 10 in iron and steel scrap smelting factory environment using PMF, PCFA and UNMIX receptor models. *Environmental Monitoring and Assessment*, *188*, 1-21. https://doi.org/10.1007/s10661-016-5585-8

Okeke, B. C., Agu, K. C., Uba, P. O., Awah, N. S., Anaukwu, C. G., Archibong, E. J., Uwanta, L. I., Ezeneche, J. N., Ezenwa, C. U., and Orji, M. U. (2015)."Wine Production from Mixed Fruits (Pineapple and of apple and pear mixed fruit jam prepared from varieties grown in Azad Jammu and Kashmir). *Journal Food Safety, 9*, 22-24

Okunowo, W.O., Okotore, R.O. and Osuntoki, A.A. (2005). The alcoholic fermentative efficiency of indigenous yeast strains of different origin on orange juice. *African Journal of Biotechnology*, *4,* 1290-1296

Othman, O. C. (2011). Physicochemical Characteristics and Levels of Inorganic Elements n Off-vine Ripened Pineapple (*Ananas comosus L.*) fruits of Dar es Salaam, Tanzania KIST. *Journal of Science and Technology*, *1*, 23 – 30.

Patil, S.K. & Shanmugasundaram, S. (2015) Physicochemical changes during ripening of monthan banana. *International Journal of Enhanced Research In Science Technology & Engineering*, 3, 18–21.

Popa, M., Mitelut, A., Popa, E., Stan, A. & Popa, V. (2018). Organic foods contribution to nutritional quality and value. *Trends Food Sci. Technol*. (*in press*) Production. *European Journal of Microbiology and Immunology*, *7*, 76-9. https://doi.org/10.1016/j.tifs.2018.01.003

Quettier-Deleu, C., Gressier, B., Vasseur, J., Dine, T., Brunet, C., Luyckx, M., & Trotin, F. (2000). Phenolic compounds and antioxidant activities of buckwheat (Fagopyrum esculentum Moench) hulls and flour. *Journal of Ethnopharmacology*, *72,* 35-42. https://doi.org/10.1016/S0378-8741(00)00196-3

Ray, P. D., Huang, B. W., & Tsuji, Y. (2012). Reactive oxygen species (ROS) homeostasis and redox

regulation in cellular signaling. *Cellular signalling*, *24*, 981-990. https://doi.org/10.1016/j.cellsig.2012.01.008

Reddy, L.V.A. & Reddy, O.V.S. (2005). Production and characterization of wine from mango fruits (Mangifera indica Linn.). *World Journal of Microbiology and Biotechnology*, *21*, 1345-1350. https://doi.org/10.1007/s11274-005-4416-9

Rivera-Espinoza, Y., Valdez-Lopez, E., & Hernandez-Sanchez, H. (2005). Characterization of a wine-like beverage obtained from sugarcane juice. *World Journal of Microbiology and Biotechnology*, *21*, 447-452. https://doi.org/10.1007/s11274-004-1878-0

Rizzon, L. A., Miele, A., & Meneguzzo, J. (2000). Avaliação da uva cv. Isabella para elaboração de vinho tinto. *Food Science and Technology*, *20*, 115-121. https://doi.org/10.1590/S0101-20612000000100022

Swami, S. B., Thakor, N. J., & Divate, A. D. (2014). Fruit wine production: a review. *Journal of Food Research and Technology*, *2*, 93-100.

Tamang, J. P., & Samuel, D. (2010). Dietary cultures and antiquity of fermented foods and beverages. *Fermented Foods and Beverages of the World*, *1*, 1-40. https://doi.org/10.1201/EBK1420094954-c1

Uraih, N. (2003). *Public Health, Food and Industrial Microbiology.* (6th ed.).The Macmillan Press, pp. 196-198.

Ukwuru, M. U. and Awah, J. I. (2013). Properties of palm wine yeast and its performance in wine making. *African Journal of Biotechnology*, *12*, 2670-2677.

USDA, (2014). U.S. Department of Agriculture, Agricultural Research Service. USDA Database for the Flavonoid Content of Selected Foods. Retrieved from http://www.ars.usda.gov/SP2UserFiles/Place/80400525/Data/Flav/Flav_R03-1.pdf (accessed September 20, 2022)

Walker, G.M. (2014). Fermentation (industrial): Media for industrial fermentations in encyclopedia of food microbiology; Batt, C., Tortorello, M.L., Eds.; Elsevier Science Publishers. https://doi.org/10.1016/B978-0-12-384730-0.00107-5

Waters, E.J., G. Alexander, R. Muhlack, K.F. Pocock, C. Colby, B.N. O'Neill, P.B. Høj, and Jones, P.R. (2005). Preventing protein haze in bottled wine. Aust. *Journal Grape Wine Resources*, *11,* 215-225. https://doi.org/10.1111/j.1755-0238.2005.tb00289.x

Wilson, S. M., Le Maguer, M., Duitschaever, C., Buteau, C. & Allen, O. B. (2003). Effect of processing treatments on the characteristics of juices and still ciders from Ontario-grown apples. *Journal of the Science of Food and Agriculture*, *83*, 215–224. https://doi.org/10.1002/jsfa.1299

Publisher: Department of Home Economics and Hospitality Management Education, University of Nigeria, Nsukka 41001, Nigeria