

Physicochemical, Sensory and Microbiological Quality of Table Wine Produced from Coconut water, Honey and Zobo

C. O. Ajogun, S. C. Achinewhu, D. B. Kiin-Kabari and O. M. Akusu

Abstract — Physicochemical, sensory and microbiological quality of table wine produced from coconut, water, honey and zobo. Coconut water was collected and mixed with Zobo at a ratio of 5:1 and with honey also at 5:1 ratio. The various mixtures were fermented with wine yeast at room temperature (28 ± 2 °C) for 7 days to produce table wine. There was no significant difference ($P > 0.05$) in the fat, protein, ash and Carbohydrate content of all the wine samples, including control (commercial red and white table wines). Total Acid and alcohol content ranged from 0.576–0.921% and 5.87–11.50%, respectively. Sugar content ranging from 11.00–12.00%, however, difference in sugar content of all the wine samples were not statistically significant ($P > 0.05$). The specific gravity of the coconut wines was significantly ($P < 0.05$) higher than those of the control (commercial red and white wine). Total yeast count (TYC) on the fresh wine after 7 days' fermentation period ranging from 7.66 Log_{10} CFU/ml to 8.91 Log_{10} CFU/ml, with sample CWHN (coconut water and honey wine without yeast) given significantly ($P < 0.05$) higher value of 8.91 Log_{10} CFU/ml. Total bacteria count (TBC) on the aged wine (after 21 days of storage) ranged from 5.145 Log_{10} CFU/ml to 6.230 Log_{10} CFU/ml with sample CWH (coconut water and honey) wine given significantly higher value of 6.23 Log_{10} CFU/ml. The taste of sample CWZ compared favourably with those of the commercial red and white wines. Sample CWZ (coconut/zobo wine) received equal overall acceptability with the commercial table wines.

Index Terms — Fermentation, Wine, Coconut, Zobo, Honey, Physicochemical, Microbiological, Sensory.

I. INTRODUCTION

Fermented beverages and alcoholic drinks are culturally and socially accepted products for consumption, drinking, entertainment, customary practices, and religious purposes. Across the globe (Europe, America, Australia, Asia, and recently, Africa), winemaking processes are popular [1]-[2]. Wine, an alcoholic beverage is produced from the fermentation of fruit juices especially grape which have a chemical balance that allows them to ferment without addition of sugar, acids, enzymes or other nutrients [3]. Many tropical and subtropical fruits, including grapes, apples, pears, apricots, berries, peaches, sugar cane, oranges, mangoes, bananas and pineapples yield good amounts of juice on extraction [3]-[4]. Upon fermentation, fruit juices

can be changed into wines [5]-[7]. Different varieties of grapes and strains of yeasts produce different types of wine. These variations result from the complex interactions between the biochemical components of the grape, the reactions involved in fermentation and the overall production process [8].

Wines are classified as natural wines having an alcoholic content of 9-14% and 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 the amount of sugar in the wine, but also the relative levels of alcohol, acids and tannins. 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% [9].

Coconut water is liquid endosperm, which formed gradually as from the third month of coconut maturation and reaching a maximum in eight months, declining as the nut ripens [10]. It is a faintly turbid to clear liquid, colourless, sweet, naturally flavoured and slightly acidic with reported pH ranging from 4.2 to 6.0 [11]. Coconut water is largely consumed all over the world, not only as a refreshing drink, but also because of its numerous therapeutic qualities. Coconut water has high mineral content such as potassium, sodium, chlorides, magnesium and phosphorus. It contains some high level of vitamins like vitamins B and ascorbic acid [12]. This high mineral and sugar content of coconut water makes it to be considered as sports drink. It is sweet drink that is sterile in its natural form and rich in amino acids like arginine, alanine, and cystine. It is used as oral rehydration fluid for elderly people and children suffering from gastroenteritis [13]. Coconut water contain cytokinins which contributes to some health benefits such as anti-carcinogenic, anti-aging and anti-thrombotic [14]. Coconut water obtained from mature nuts, when harvested for the production of copra and coconut oil, is wasted on a large scale in several tropical countries.

Honey is a sweet (mostly consisting of monosaccharides of fructose and glucose) jelly-like substance made from the nectar of flowers by bees. The high sugar content present in honey predisposes it as a good substrate for yeast fermentation to produce alcohol and carbon dioxide gas. Honey wines have ancient history in Asia and were regarded

Published on September 26, 2020.

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as the beverage for the nobles and gods, for spiritual wisdom and life [15].

Roselle (*Hibiscus sabdariffa* L.) is a commonly grown plant and is extensively grown in Nigeria, particularly in the country's North-Eastern and middle belt areas [16]. It is herb of economic importance as it can serve as a source of essential minerals and vitamins such as riboflavin, niacin, calcium and iron [17]. The zobo drink has demonstrated its immense potential to be great source of carbohydrate, vitamin C and protein which is the significant reasons for drinking juice [18].

In spite of the numerous advantages of coconut water, zobo and honey, diversity in their application is still limited in Nigeria. The use of coconut water in Nigeria is very limited and most time wasted when coconut is used for other purposes. Thus, the objective of this work was to monitor and evaluate the changes in physicochemical properties and microbiological quality of coconut (*Cocos nucifera* L) water, honey and zobo 'must' during fermentation, in wine production.

II. MATERIALS AND METHODS

Mature Coconut fruits, wine yeast, sugar, honey and zobo (Roselle Calyx) were procured from Oil Mill Port Harcourt, Rivers State, Nigeria, and transported to Rivers Stater University.

A. Preparation of Coconut Wine

Mature coconut was unshelled, the water collected and mixed with honey and zobo for wine production, as illustrated in Fig. 1.

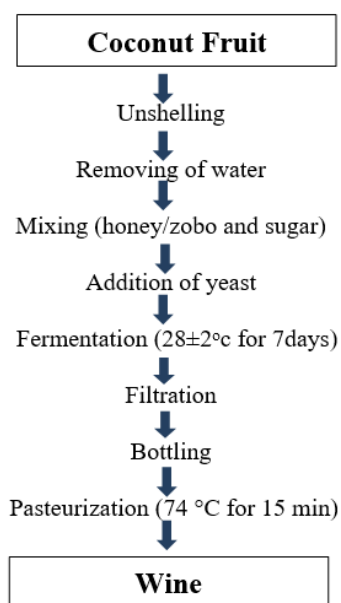


Fig. 1. Production of Table Wine from Coconut Water, Zobo and Honey.

B. Inoculum development

Cells suspension of commercial wine yeast developed by inoculating into 250 ml of YEPG broth (20 g/l glucose; 10 g/l yeast extract; 10 g/l peptone) in 500 ml conical flask, aerated by shaking on shaker and incubated at 28- 30 °C for

4 days, then pitched inoculum developed into the fermenter containing the must [19].

C. Preparation of "Must"

"Must" preparation was carried out according to the method of [20]. Dried zobo calyces (300 gram) extract was obtained by boiling in 2000 ml, the extract separated from the calyces and stored in the refrigerator. Coconut water was obtained by carefully cracking the nut, not allowing spill. Metabisulphite 0.2 g was added to the coconut water. Coconut-zobo blend was mixed in the ratio of 5:1 to obtain 3000 ml. The 'must' (coconut-zobo blend) was chaptalized up to 22 % (w/v) brix by adding granulated sucrose (240 g/l), while Coconut-honey blend was prepared by adding 500 ml of honey to 2500 ml of coconut water. Ammonium sulphate 2.53 g/l; potassium dihydrogen phosphate 1.3 g/l; yeast extract 0.1 g/l and magnesium sulphate hydrate 0.1 g/l for supplementation. Two hundred milliliters of the propagated yeast cells at 10^8 cells were pitched into the 'must'.

D. Fermentation Process

Primary Fermentation; Fermentation of musts were carried out in 10 liters containers at room temperature (28 ± 2 °C). All the treatments (coconut water 'must', coconut water-honey 'must', coconut water-zobo 'must' and coconut water-honey without yeas 'must'. were allowed to ferment for 6 days. Aliquot of the musts obtained were used for physiochemical and microbiological analysis. During this period, microbial analysis, sugar content, specific gravity and pH of the 'must' was monitored on daily basis.

Secondary Fermentation: After the primary fermentation, an air tap was fixed to the fermenting vessel to indicate the end of primary fermentation. Secondary fermentation was terminated after 7 days and then the wine was filtered. The microbial analysis sugar content, specific gravity, titratable acidity and pH of the wine was monitored at the end of the secondary fermentation.

Clarification and Racking: After secondary fermentation, the wine was racked weekly for 3 weeks to clear the wine.

Aging: After the racking, the wine was kept in the refrigerator for maturation (2 weeks) and then packaged, pasteurized and stored for further analysis.

E. Proximate Composition of Wine

Proximate Composition, including moisture, fat, ash, protein and carbohydrate was determined using standard methods [21].

F. Specific Gravity of Wine produced from Coconut water, Zobo and Horney

Using standard method [21]. Fifty ml specific gravity bottle was thoroughly cleaned with distilled water, dried in an oven for 50 °C allowed to cool. The weight of the cooled dried bottle (W1) was recorded. The dried bottle was filled with deionized water and surface of the bottle was cleaned with a cotton wool and weighed as (W2). The bottle was empty and cleaned twice with 10ml of the 'must' thereafter the bottle was filled to the brim with the 'must' and the bottle cleaned with cotton wool and weighed as (W3). This was done at 24 hours' interval of 7 days' fermentation period. The specific gravity (S.G) was calculated.

$$S.G = \frac{W_3 - W_2}{W_2 - W_1} = \frac{S}{W}$$

where

S = weight of volume of 'must' ($w_3 - w_1$)

W = weight of volume of water ($w_2 - w_1$)

G. Alcohol content of Wine produced from Coconut water, Zobo and Horney

The alcohol content of the wine was determined using specific gravity as described by [22], and calculated as follows:

$$\text{Percentage alcohol} = (\text{OG} - \text{FG}) \times 131.25$$

where:

OG = Original Gravity of the sample.

FG = Final Gravity of the sample.

131.25= constant based on the absolute weight of pure water and ethanol.

H. Microbial monitoring and analysis

All the media used are TM[®] media and prepared in accordance with the manufacturer's instruction: Nutrient agar 28 g/l; MacConkey agar 52 g/l; Potato Dextrose Agar 39 g/l and de Man Rogosa and Sharpe agar 66.73 g/l. Tenfold serial dilution of each sample was carried out, 0.1 ml volume was plated out from 10⁻⁶ dilution factor and spread on solid agar plate, incubated at ambient temperature for 48 hours.

I. Total Bacteria count (TBC)

The microbiological analysis was carried out according to methods described by [23]. Plate count agar was used for enumeration of bacteria. A well homogenized sample was serially diluted with 0.1% peptone water up to 10⁻⁶. One ml aliquot from a suitable dilution was transferred aseptically into sterile petri dishes. To each plate about 15ml of melted and cooled nutrient agar was added. The inoculate was evenly mixed with media by rotating the plates and allowed to solidify. The inverted plate was incubated for 48hours. The TBC (cfu/ml) was determined using a colony counter.

J. Yeast and Mould Enumeration

Potato dextrose agar (PDA) was used for enumeration of yeast and mould. Well homogenized samples were serially diluted with 0.1%pepetone water up to 10⁻⁶. Aliquots (0.1 ml) from a suitable dilution were transferred aseptically into solidified PDA plates. Samples were spread all over the surface of the plates using sterile bent glass rod. The plates were then incubated for 72 hrs at 28 °C. Counting (cfu/ml) were carried out by using colony counter [23].

K. Total Coliform Test

The total coliform test was carried out by multiple tube techniques according to [24]. One (1g) of wine sample was diluted in 9 ml distilled water. A serial dilution was then prepared up to 10⁻³. The sample was cultured in MacConkey agar and incubated at 37 °C for 48 hrs.

L. Sensory Evaluation

The sensory evaluation of the wine was carried out by 20 semi trained panelists from students and staff of the department of Food Science and Technology, Rivers State

University, Port Harcourt. Samples were scored for taste, aroma, colour, clarity and overall acceptability using a 9-point hedonic scale according to the method of [25]. commercial wine was used as control.

M. Statistical Analysis

All the analyses were carried out in triplicate. Data obtained were subjected to Analysis of variance (ANOVA), differences between means were evaluated using Tukey's multiple comparison test, and significance accepted at P≤ 0.05 level. The statistical package in Minitab 16 computer program was used.

III. RESULTS AND DISCUSSION

A. Changes in Specific Gravity (SG) of Coconut/Honey/Zobo 'Must' During Fermentation

Result for physicochemical properties of "must" from coconut water/honey/zobo mixture showed that Specific Gravity of the "must" reduced significantly with fermentation time (Fig. 2). These could be due to increased metabolic activities leading to exhaustion of available nutrients with the concomitant production of alcohol, which has lower SG [26]. The specific gravity (SG) of must from coconut water without yeast, reduced significantly (P<0.05) from 1.157 on day one of fermentation to 1.0168 on day six. For sample CW (coconut water), the SG was constant up to day 3 and reduced significantly to 0.961 on day 4,5, and 6. SG of sample CWZ (coconut water and zobo) reduced from 1.1763 on day 1 to 1.0382 on day 2 and remained relatively constant to the sixth day of fermentation. Reduction in specific gravity of coconut must during fermentation from 1.015 to 0.886 had earlier been reported by [27]. Awe [28] also reported reduction in SG of pawpaw must from 1.060 to 0.996 during fermentation.

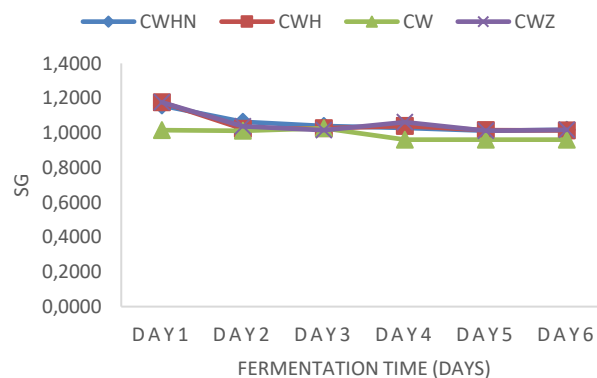


Fig. 2. Changes in Specific Gravity (SG) of Coconut/Honey/Zobo Must During Fermentation.

Key: CWZ = coconut water and zobo, CW = coconut water, CWH= coconut water and honey, CWHN= coconut water and honey (no yeast).

B. Changes in pH of Coconut/Honey/Zobo 'Must' During Fermentation

pH of "must" from coconut water (CW) reduced from 4.90 on day one to 2.40 on day 3 and remained constant up to day 6 (Fig. 3). pH of sample CWHN (coconut water and honey without yeast) reduced from 4.35 to 3.20 after six days of fermentation. pH of sample CWH was relatively

constant from day 1 to day 2 and reduced significantly ($P < 0.05$) to 3.05 on day 6. The drop in pH and corresponding increase in titratable acidity of must during aerobic and anaerobic fermentation stages are attributable to yeast metabolism. These also showed acidification of the medium as fermentation progresses, which is crucial to wine production. 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 mean a poor fermentation [29]. Low pH is known to give yeast comparative advantage in natural environments. A similar observation has been reported by [30] in their study on Mixed Fruits (Pineapple and Watermelon). Ogodo et al. [31] also reported decrease in pH and an increase in acidity during production of mixed fruit wines of pawpaw, banana and watermelon. The present report is also consistent with the report of other researcher for some tropical fruit wines such as tundu [32], sweet potato [33] and banana [34]. The decrease in pH and an increase in acidity could be attributed to production and accumulation of organic acids during fermentation

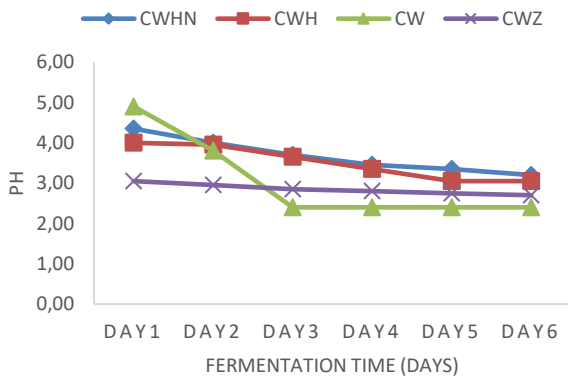


Fig. 2. Changes in pH of Coconut, Honey and Zobo Must During Fermentation.

Key: CWZ = coconut water and zobo, CW = coconut water, CWH= coconut water and honey, CWHN= coconut water and honey no yeast.

C. Changes in Percentage Sugar Content (Brix) of Coconut Wine during Fermentation

From the result in Fig. 4, the sugar content of the ‘must’ all decreased after 6 days of fermentation. Sample CW decreased from 21.00% to 9.00%. Sugar content of ‘must’ from coconut water and zobo (CWZ) reduced from 17.20% to 8.00%, samples CWHN reduced from 13.50% to 9.00%, while sample CWH experience a rapid decreased on day1 9.5% and became constant from day 3 to day4 8.0% of fermentation. This result agreed with the reports of [6] who observed a decrease in the sugar content of overripe mango wine.

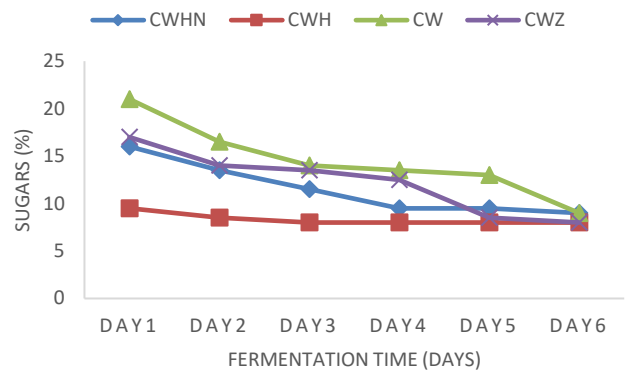


Fig. 4. Changes in Percentage Sugar Content (Brix) of Coconut/Honey/Zobo Must During Fermentation.

Key: CWZ = coconut water and zobo, CW = coconut water, CWH= coconut water and honey, CWHN= coconut water and honey without yeast.

D. Total Yeast Count (Log₁₀ CFU/ml) of Coconut/Honey/Zobo ‘Must’ during Fermentation

As shown in Table 1, the yeast count ranged from 7.45 to 7.66 log₁₀ CFU/ml, 7.66 to 8.84 log₁₀ CFU/ml, 8.56-8.98 log₁₀ CFU/ml and 6.60 - 8.08 log₁₀ CFU/ml, for samples CWZ, CWH, CWHN and CW respectively. There was significant ($P > 0.05$) change in the yeast count of sample CWZ on day 2 of fermentation. The Total yeast count of sample CWH and CW were constant from day 2 to 5, but decreased significant ($P < 0.05$) on the sixth day of fermentation to 8.19 log₁₀ CFU/ml for sample CWH and increased significant ($P < 0.05$) on sixth day of fermentation to 8.08 log₁₀ CFU/ml, for sample CW. The increase in the total yeast count during fermentation can be attributed to the presence of utilizable sugar (sucrose) and yeast nutrient. The daily aeration of the fermenting must also have aided rapid multiplication of the yeast cells [29]-[35].

TABLE 1: TOTAL YEAST COUNT (LOG₁₀ CFU/ML) OF COCONUT/HONEY/ZOBO ‘MUST’ DURING FERMENTATION

Fermentation Time	Samples			
	CWZ	CWH	CWHN	CW
Day1	7.57 ^{ab} ±0.082	7.66 ^c ±0.017	8.85 ^c ±0.017	6.6 ^c ±0.000
Day2	7.45 ^b ±0.002	8.84 ^a ±0.045	8.92 ^{ab} ±0.011	7.61 ^b ±0.015
Day3	7.65 ^a ±0.006	8.81 ^a ±0.001	8.56 ^c ±0.031	7.82 ^b ±0.028
Day4	7.62 ^a ±0.014	8.67 ^a ±0.148	8.98 ^a ±0.006	7.84 ^b ±0.027
Day5	7.64 ^a ±0.006	8.42 ^{ab} ±0.163	8.74 ^d ±0.006	7.73 ^b ±0.136
Day6	7.66 ^a ±0.013	8.19 ^b ±0.157	8.91 ^{bc} ±0.011	8.08 ^a ±0.010

Values are means ± standard deviation of duplicate samples.

Mean values bearing different superscript in the same column differ significantly ($P < 0.05$).

Key: CWZ = coconut water and zobo, CW = coconut water, CWH= coconut water and honey, CWHN= coconut water and honey without yeast.

E. Total Coliform Count (Log₁₀ CFU/ml) of Coconut/Honey/Zobo ‘Must’ during Fermentation

No coliform growth was seen in samples CWZ and CW ‘Must’ throughout the period of fermentation (Table 2). No growth was also observed in the first and fort day for sample CWH Must, while the Total coliform count (TCC) of 7.92, 7.48, 7.30 and 7.00 Log₁₀ CFU/ml shown on days 2,3,5 and 6 where not statistically different ($P > 0.05$). Lower microbial

count of the wine may specifically be as a result of the presence of alcohol, organic acids and increase in total acidity. low pH inhibits pathogenic and putrefactive bacterial activity, thus affecting bacterial growth and metabolism [36]-[38]. Total coliform of 8.09 Log₁₀ CFU/ml to 7.78 Log₁₀ CFU/ml was seen in sample CWHN from day one to six, these values however, showed significant (P<0.05) drop on day 4 and 5 to 7.00 Log₁₀ CFU/ml. the presence of coliforms generally signifies poor sanitary condition. The ICMSF [39] recommended absence of coliform in wines.

TABLE 2: TOTAL COLIFORM COUNT (LOG₁₀ CFU/ML) OF COCONUT/HONEY/ZOBO 'MUST' DURING FERMENTATION

Fermentation Time	Samples			
	CWZ	CWH	CWHN	CW
Day1	NG	NG	8.09 ^a ±0.125	NG
Day2	NG	7.92 ^a ±0.879	8.19 ^a ±0.020	NG
Day3	NG	7.48 ^a ±0.000	7.87 ^a ±0.041	NG
Day4	NG	NG	7.00 ^b ±0.000	NG
Day5	NG	7.30 ^a ±0.426	7.00 ^b ±0.000	NG
Day6	NG	7.00 ^a ±0.000	7.78 ^a ±0.249	NG

Values are means ± standard deviation of duplicate samples. Mean values bearing different superscript in the same column differ significantly (P<0.05).
Key: CWZ = coconut water and zobo, CW = coconut water, CWH= coconut water and honey, CWHN= coconut water and honey without yeast, NG= No growth.

F. Total Bacteria Count (Log₁₀ CFU/ml) of Coconut/Honey/Zobo 'Must' during Fermentation

From the result, no growth (NG) was noticed in samples CWZ and CW (Table 3). Bacteria growth noticed on both samples CWH and CWHN could be from the honey use in chaptalization. From the result of samples CWH and CWHN as the fermentation progresses the bacterial growth was also reducing. Inhibition of bacterial growth is probably due to alcohol production. Alcohol inhibits bacterial growth by plasmolyzing bacterial cell walls [40]. The TBC of sample CWHN reduced significantly (P<0.05) from 8.87 Log₁₀ CFU/ml on day 1 to 7.76 Log₁₀ CFU/ml after six days of fermentation. Reduction in TBC of samples CWH and CWHN could also be due to reduction in pH and increase in Total titrable acidity.

TABLE 3: TOTAL BACTERIA COUNT (LOG₁₀ CFU/ML) OF COCONUT/HONEY/ZOBO 'MUST' DURING FERMENTATION

Fermentation Time	Samples			
	CWZ	CWH	CWHN	CW
Day1	NG	NG	8.87 ^a ±0.004	NG
Day2	NG	NG	8.14 ^{bc} ±0.197	NG
Day3	NG	NG	8.26 ^b ±0.000	NG
Day4	NG	8.720 ^a ±0.018	8.16 ^b ±0.021	NG
Day5	NG	7.70 ^b ±0.000	7.78 ^{cd} ±0.000	NG
Day6	NG	7.500 ^b ±0.281	7.76 ^d ±0.116	NG

Values are means ± standard deviation of duplicate samples. Mean values bearing different superscript in the same column differ significantly (P<0.05).
Key: CWZ = coconut water and zobo, CW = coconut water, CWH= coconut water and honey, CWHN= coconut water and honey without yeast, NG= No growth.

G. Proximate Composition of Aged Table Wine Produced from Coconut Water and its Blends with Zobo and Honey

The results of the proximate composition (Table 4) showed level of significance between the moisture content only. The moisture, fat, protein, ash and Carbohydrate content ranged from 93.90% - 95.986%, 1.479- 2.435%, 0.657 - 1.532%, 0.225 - 0.748% and 1.093 - 2.968%, respectively. Moisture content of the control Red wine (RW) and sample CW (coconut water wine) were significantly (P<0.05) higher. There was no significant difference (P>0.05) in the fat, protein, ash and Carbohydrate content of all the wine samples, including control (red and white wines). High moisture content makes beverage suitable as a refreshing and quench- thirsting product which is a characteristic of good beverage. This is similar to the report given by [30]. A minimal amount of ash was obtained. This indicates the presence of mineral component in the wine. This was in agreement with earlier reports of 0.5% ash in wine made from fruit juices [41]. Low fat content suggests that the wines could provide protection against excess body lipids (cholesterol) and it also demonstrate the desirable nutritive quality of fruit wine as reported by [28]. Low protein content of the wines offers suitability for maintenance of cellular organization, as reported by [42]. A decrease in the carbohydrate content of the wine was observed. This might be due to decline in the sugar content as a result of rapid and effective utilization of the sugar available in the must by the yeast cells leading to the fermentation of the must [43].

TABLE 4. PROXIMATE COMPOSITION OF AGED TABLE WINE PRODUCED FROM COCONUT WATER AND ITS BLENDS WITH ZOBO AND HONEY.

Samples	Moisture (%)	Fat (%)	Protein (%)	Ash (%)	Cho (%)
CWHN	93.941 ^b ±0.052	2.244 ^a ±0.412	0.863 ^a ±0.000	0.748 ^a ±0.422	2.205 ^a ±0.041
CWH	94.723 ^b ±0.013	2.435 ^a ±0.034	1.327 ^a ±0.302	0.424 ^a ±0.106	1.093 ^a ±0.173
RW	95.986 ^a ±0.169	1.479 ^a ±0.288	0.657 ^a ±0.292	0.225 ^a ±0.036	1.655 ^a ±0.786
WW	95.811 ^{ab} ±0.738	1.962 ^a ±0.148	0.638 ^a ±0.000	0.342 ^a ±0.210	2.968 ^a ±1.430
CW	95.953 ^a ±0.878	1.801 ^a ±0.016	1.532 ^a ±0.301	0.424 ^a ±0.177	1.610 ^a ±0.849
CWZ	93.900 ^b ±0.213	1.814 ^a ±0.389	1.075 ^a ±0.204	0.474 ^a ±0.105	2.738 ^a ±0.911

Values are means ± standard deviation of triplicate samples. Mean values bearing different superscript in the same column differ significantly (P<0.05).
Key: CWZ = coconut water and zobo wine, CW = coconut water wine, CWH= coconut water and honey wine, CWHN= coconut water and honey no yeast wine, RW = commercial red wine (control), WW = commercial white wine (control).

H. Physicochemical Properties of Aged Table Wine Produced from Coconut Water and its Blends with Zobo and Honey

Results for the physicochemical properties of Table wine produced from coconut water and its blends with Zobo and honey is presented in Table 5. Sugar content ranging from 11.00% - 12.00%, however, difference in sugar content of all the wine samples were not statistically significant (P>0.05). The sugar content was higher than 2.4% reported by [43] for 'Blaufrankish' commercial table wine. pH value ranged from 2.825 - 3.59, the pH value of the coconut wine

compared with those of the control except sample CWZ. The specific gravity of the coconut wine was significantly ($P<0.05$) higher than those of the control red and white wine. Total Acid and alcohol content ranged from 0.576 – 0.921% and 5.87 – 11.50%, respectively. The alcohol content of samples CWHN, CWH compared favourably with those of the control red and white wines. Alcohol content of $> 5\%$ was comparable with moderate grape wines [44]-[45]. According to [46] a good table wine must have alcohol content between 8 and 14%. High alcohols are known to be important precursors for the formation of esters, which are associated with pleasant aromas [47]. High sugar content of more than 11% indicates that the wines were not dry table wines [9].

TABLE 5: PHYSICO-CHEMICAL PROPERTIES OF AGED TABLE WINE PRODUCED FROM COCONUT WATER AND ITS BLENDS WITH ZOBO AND HONEY

Samples	Sugar (%)	pH	SG	TA (%)	ROH (%)
CWHN	11.500 ^a ±0.707	3.415 ^{ab} ±0.120	1.011 ^a ±0.000	0.717 ^{bc} ±0.047	10.015 ^c ±0.007
CWH	11.500 ^a ±0.707	3.350 ^{ab} ±0.071	1.009 ^{ab} ±0.001	0.576 ^c ±0.004	10.500 ^b ±0.000
RW	11.000 ^a ±0.000	3.590 ^a ±0.014	0.996 ^c ±0.001	0.703 ^{bc} ±0.021	11.500 ^a ±0.000
WW	11.500 ^a ±0.707	3.375 ^{ab} ±0.035	1.003 ^c ±0.000	0.921 ^a ±0.014	10.500 ^b ±0.000
CW	12.000 ^a ±0.000	3.195 ^b ±0.007	1.000 ^d ±0.001	0.853 ^{ab} ±0.094	5.870 ^e ±0.184
CWZ	12.000 ^a ±0.000	2.825 ^c ±0.035	1.007 ^b ±0.001	0.690 ^{bc} ±0.051	9.605 ^d ±0.007

Values are means ± standard deviation of triplicate samples. Mean values bearing different superscript in the same column differ significantly ($P<0.05$).

Key: CWZ = coconut water and zobo wine, CW = coconut water wine, CWH= coconut water and honey wine, CWHN= coconut water and honey no yeast wine, RW = commercial red wine (control), WW = commercial white wine (control), SG = specific gravity, TA = total acid, ROH = alcohol.

1. Microbiological Quality of Aged Table Wine Produced from Coconut Water and its Blends with Zobo and Honey

From Table 6 total bacteria count (TBC) ranged from 5.145 Log₁₀CFU/ml to 6.230 Log₁₀CFU/ml with sample CWH (coconut water and honey) wine given significantly higher value of 6.23 Log₁₀CFU/ml. Total coliform (TCC) ranged from 4.602-5.301 Log₁₀CFU/ml with samples RW (control red wine) and CWZ given significantly ($P<0.05$) higher and lower values respectively. Total L. bacillus count ranged from 4.875-5.431 Log₁₀CFU/ml with no growth seen in sample CW. Total yeast count (TYC) ranged from 5.204-5.663 Log₁₀CFU/ml. these agreed with values reported by earlier researchers for water melon wine [35]. yeast count in samples CWH and CW were not significantly ($P>0.05$) different. Significantly ($P<0.05$) higher mould count of 4.954 Log₁₀CFU/ml was noticed in the control white wine (WW). While no mould growth was seen in samples RW (control Red wine) and CWZ. This was probably due to better hygiene practice during the process of fermentation. Fermentation for production of beverages like wine depends on the ability and performance of the yeast to convert sugar contents of the substrates to alcohol and esters. The Coconut water, zobo and honey provided all the nutrients necessary in the completion of the fermentation, hence the fermenting ‘must’ was not induced with any artificial nutrient. The

result of this work correlates with those of [48] that fermented water melon, banana and pineapple; and obtained quality wine product.

TABLE 6: MICROBIOLOGICAL QUALITY (LOG₁₀CFU/ML) OF AGED TABLE WINE PRODUCED FROM COCONUT WATER AND ITS BLENDS WITH ZOBO AND HONEY

Wine Samples	TBC	TCC	TLBC	TYC	TMC
CWHN	5.934 ^c ±0.005	5.079 ^d ±0.000	5.431 ^a ±0.016	NG	4.477 ^d ±0.000
CWH	6.230 ^a ±0.026	5.204 ^b ±0.027	5.041 ^b ±0.000	5.580 ^b ±0.000	4.813 ^b ±0.000
RW	5.732 ^b ±0.008	5.301 ^a ±0.000	4.954 ^c ±0.000	5.204 ^d ±0.027	NG
WW	5.940 ^{bc} ±0.005	4.653 ^e ±0.010	5.078 ^b ±0.036	5.255 ^c ±0.024	4.954 ^a ±0.005
CW	5.145 ^e ±0.031	5.114 ^e ±0.000	NG	5.580 ^b ±0.011	4.544 ^c ±0.012
CWZ	5.982 ^b ±0.005	4.602 ^f ±0.000	4.875 ^d ±0.000	5.663 ^a ±0.000	NG

Values are means ± standard deviation of triplicate samples. Mean values bearing different superscript in the same column differ significantly ($P<0.05$).

Key: CWZ = coconut water and zobo wine, CW = coconut water wine, CWH= coconut water and honey wine, CWHN= coconut water and honey no yeast wine, RW = commercial red wine (control), WW = commercial white wine (control), NG= No growth, TBC = total bacterial count, TCC = total coliform count, TYC = total yeast count, TLBC = total L. bacillus count, TMC = total mold count

J. Sensory Properties of Table Wine Produced from Coconut Water and its Blends with Zobo and Honey

From the result in Table 7, Colour score for samples RW, WW, CW and CWZ were not significantly ($P>0.05$) different. The taste of sample CW compared favourably with those of the commercial red and white wines. The flavour of sample CWZ (coconut/zobo wine) also compared favourably with the commercial red and white wines. Clarify score ranged from 5.2 – 7.64 with sample CWZ receiving significantly ($P<0.05$) higher score of 7.64. sample CWZ received equal overall acceptability with the commercial wines. Presence of undesired microbes during different stages of winemaking can produce volatile acidity, off-flavors and polysaccharide hazes, all of which can diminish the quality and acceptability of the final product [49].

TABLE 7. SENSORY PROPERTIES OF TABLE WINE PRODUCED FROM COCONUT WATER AND ITS BLENDS WITH ZOBO AND HONEY.

Samples	Colour	Taste	Flavour	Clarity	Overall Acceptability
CWHN	5.16 ^b ±1.772	4.68 ^b ±2.056	4.96 ^b ±1.881	5.20 ^c ±2.141	5.08 ^b ±1.754
CWH	5.64 ^b ±1.680	7.00 ^a ±1.708	5.16 ^b ±1.841	5.88 ^c ±1.453	5.44 ^b ±1.530
RW	7.48 ^a ±1.503	7.08 ^a ±1.152	6.96 ^a ±1.306	7.32 ^{ab} ±1.282	7.28 ^a ±0.843
WW	7.48 ^a ±1.686	7.24 ^a ±1.451	6.72 ^a ±1.720	7.32 ^{ab} ±1.376	7.24 ^a ±1.091
CW	5.40 ^a ±2.273	4.20 ^a ±2.082	4.48 ^b ±2.002	6.00 ^{bc} ±2.160	5.16 ^b ±1.930
CWZ	8.16 ^a ±0.987	7.28 ^a ±1.646	7.04 ^a ±1.428	7.64 ^a ±0.952	7.68 ^a ±0.852

Values are means ± standard deviation of twenty-five responses. Mean values bearing different superscript in the same column differ significantly ($P<0.05$).

Key: CWZ = coconut water + zobo wine, CW = coconut water wine, CWH= coconut water + honey wine, RW = commercial red wine (control), WW = commercial white wine (control), CWHN= coconut water and honey no yeast wine.

IV. CONCLUSION

pH of 'must' from coconut water (CW) reduced from 4.90 on day one to 2.40 on day 3 and remained constant up to day 6. Decrease in specific gravity of the fermented 'must' is due to increased metabolic activities leading to exhaustion of available nutrients with the concomitant production of alcohol. Sugar content of the 'must' was shown to decrease during fermentation. 'Must' from coconut/zobo (CWZ) and those from coconut water (CW) did not record any coliform nor bacteria growth all through the period of fermentation. From the results, no coliform and bacterial growth were seen in fresh table wine produced from coconut water (CW) and those produced from blends of coconut water and 'zobo' (CWZ), due to observed low pH value of 2.4 and 2.7, respectively. Total coliform count in all the coconut wine samples were significantly ($P < 0.05$) lower than those observed in the control (commercial red wine). There was no significant ($P > 0.05$) difference in fat, protein, ash and carbohydrate content of the wine samples, including control (commercial red and white wine). The alcohol content of wine produced from coconut water and honey wine without yeast (CWHH) and coconut water and Horney wine (CWH) were respectively 10.015% and 10.50%, these compared favourably with those of the commercial red and white wines. High sugar content of all the coconut wine samples indicates that they were not dry table wines. Sample CWZ (coconut water/zobo wine) received equal overall acceptability with the commercial table wines. In conclusion, this study has shown that it is possible to produce wines from coconut water and its blends with good microbiological standard. Production of wine from these fruits could help reduce the level of post-harvest loss and increase variety of wines.

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