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Quality Assessment of Water Melon (*Citruluslanatus)* Wine Produced Using *Saccharomyces cerevisiae* Isolated from Palm Wine

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Abstract: This study was aimed at investigating the suitability of water melon juice as substrate for wine production and the efficiency of *Saccharomyces cerevisiae* isolated from palm wine for alcoholic fermentation of the juice. The yeast was isolated using pour plate technique and was identified using sugar utilization test, screened for ethanol tolerance test and was finally identified using API 20C AUX kit, as *Saccharomyces cerevisiae*. The yeast was purified and used to pitch water melon must using 0.5 McFarland standard and was allowed to undergo fermentation for three (3) days. Variations in temperature, pH, total titrable acidity, volatile acidity and total yeast count were determined at 6 hour intervals. The must and the produced wine were subjected to proximate and physico chemical analysis. The produced wine was subjected to microbial and sensory evaluation using seven point hedonic scales by 10 panelists. A total of 19 yeasts were isolated but only 5 isolates were suspected to have the same colony morphology as *Saccharomyces cerevisiae* after microscopy. The isolates assimilated mainly glucose, maltose and sucrose, but not fructose, lactose and mannitol. The ethanol tolerance was found to be between 2- 8% ethanol tolerant. The temperature ranged between 25- 30°C. The pH and volatile acidity decreased while total titrable acidity increased as the fermentation progressed. The total yeast count ranged between 1.9 - 8.2 × 10^7CFU/mL. Results of the proximate composition showed that there were significant difference ($p< 0.05$) in the moisture, crude protein, carbohydrate and total energy between the water melon must and wine, except for percentage ash and fat which showed no significant difference ($p< 0.05$). There was reduction in specific gravity from 1.075 to 1.020 and brix from 2.9220^0 to 0.5465^0 Brix and resultant increase in the alcohol concentration from 0 to 7.36%. Microbial analysis showed that there was no microbial contamination of the wine. Sensory evaluation on the wine showed that there was no significant difference ($p< 0.05$) in aroma, colour, clarity and general acceptability between the sweetened and unsweetened wine. However, there was significant difference ($p > 0.05$) for taste between the two wines. This study revealed that a tropically available fruit in Nigeria like water melon is suitable for fruit wine production with *Saccharomyces cerevisiae* from palm wine, with high acceptability and good microbiological standard.

Keywords: Water Melon, Palm Wine, Wine, Alcoholic Fermentation, *Saccharomyces cerevisiae*

1. Introduction

Watermelon (*Citrulluslanatus*) is a fruit which belongs to the family of cucumbitacea. The fruit is round with reddish mesocarp having a lot of seed and is mostly grown in the northern part of Nigeria. It contains vitamin B1 and B6, potassium and magnesium in addition to vitamin A and C which is generally common to all fruits and vegetables [1]. Watermelon (*Citrululunatus*) is rich in carotenoids some of which include lycopene, phytofluene, phytoene, beta-carotene, lutein and neurospnene. Lycopene makes up the majority of the carotenoids of watermelon. Carotenoids have antioxidant activity and free scavenging property thereby help in reducing the risk of cancers, cardiovascular diseases, arteriosclerosis diabetes and arthritis and protects against macular degeneration. A watermelon is nominally 60% flesh

and about 90% of the flesh is juicy which contains 7 to 10% (w/v) sugar. Thus, over 50% of the watermelon is readily fermentable liquid [2]. The nutritional profile of watermelon is full array of nutrients, including carbohydrates, sugar, soluble and insoluble fiber, sodium, vitamins, minerals, fatty acids, amino acids and more. A serving cup of watermelon contains 12.31mg of vitamin C, 864.88IU of vitamin A, 170.24MG of potassium and 45.60 calories [3].

In Nigeria, watermelon are fermented, blended and consumed as juice, nectars, fruit cocktails and can also be used as an appetizer or snacks, depending on how it is prepared [4]. The seeds are also reported to possess medicinal properties and are used to treat chronic or acute eczema. It contains high levels of proteins, lipids and is a rich source of carbohydrate and fibre. Arginine, glutamic acid, aspartic acid and leucine are the predominant amino acids in watermelon proteins. Reports are also available on the biological value, true digestibility, protein efficiency ratio and net protein utilization of watermelon seeds [5]. Moreover, they are used as a domestic remedy for urinary tract infection, hepatic congestion, catarrh, worm remedy, abnormal blood pressure [6]. The production of wine from common fruits could help reduce the level of post-harvest losses and increases the variety of wines [7].

Wine is any alcoholic beverage produced from juices of variety of fruits by fermentative action of microorganisms either spontaneously or seeding with a particular strain mainly of yeast species to adopt a particular quality of wine [8]. Grapes are usually preferred because of the natural chemical balance of the grape juice which aids their fermentation process without the addition of sugars, acids, enzymes, or other nutrients. However, fruits such as banana, cucumber, pineapple, watermelon and other fruits are used in wine production [9-11].

Palm wine is the fermented sap of the tropical plant of the *palmae* family. It is produced and consumed in very large quantities in the Southeastern Nigeria. It contains nutritionally important components including amino acids, proteins, Vitamins and sugar. These make this wine a veritable medium for the growth of a consortium of microorganisms, where growth in turn, change the physicochemical conditions of the wine giving rise to competition and succession of organism [12]. Palm wine is tapped from the sap of *Elaes*i Species and the sap of *Raphia* Species which contains a heavy suspension of live yeasts and bacteria. Most studies on palm win have reported its potentials are source of yeast isolate for the fermentation industries. Reference [12] in their study isolated seventeen yeast strains, four belonging to the species of *Candida*, twelve to the genus of *Saccharomyces* and one to*Endomycopsis* species. This research is aimed at investigating the suitability of water melon juice as substrate for wine production and the efficiency of *Saccharomyces cerevisiae* isolated from palm wine for alcoholic fermentation of the juice.

2. Materials and Methods

2.1. Collection of Samples

The watermelons were purchased from railway station market, Barnawa in Kaduna State. The palm wine from which the yeast was isolated was obtained from Jankasa, Kaura LGA, Kaduna state of northern Nigeria.

2.2. Isolation and Identification of Yeast Cell

Sabouraud Dextrose Agar (SDA) was used as medium for isolation. The medium was prepared according to manufacturer's instruction and supplemented with 40mg/L Chloramphenicol for selective enumeration of yeast. Exactly 25ml of the palm wine was diluted with 225ml of sterile water and agitated for even distribution. Exactly 25ml of the solution was cultured on SDA using pour plate techniques and incubated at 37°C for 24hours [11]. The yeast strain was identified according to the method of [13] and carbohydrate utilization test was carried out according to the method of [11]. The yeast isolates was characterized to specie level using Analytical Profile Index (API) 20C AUX kit (BIOMERIEUX).

2.3. Determination of Ethanol Tolerance of the Yeast Isolate

Sabouraud Dextrose Agar (SDA) was used for ethanol tolerance test. The medium was autoclaved in bijou bottles and transferred to a water bath (45^oC). Various concentration of absolute ethanol from 2% to 16% (2%, 4%, 6%, 8%, 10%, 12%, 14%, and 16%) was added to different bottles of the same medium to constitute varying percentages of ethanol. The medium was poured into various petri dishes, allowed to solidify and then inoculated with *Saccharomyces cerevisiae*. All cultures were incubated at 27°C for 48 hours [14].

2.4. Preparation of Watermelon Must (Juice)

The exterior surfaces of the watermelon fruit was washed thoroughly with soapy water and rinse with distilled water to remove any possible contaminant. The fruit was cut longitudinally into four parts and the seeds were removed with a sterile knife. The inner juicy part of watermelon was removed, sliced and blended in an electric blender. The resulting slurry was filtered with a muslin cloth to obtain a clear pink liquid. The must was analyzed for the proximate and physico-chemical parameters. The must was thenpasteurised at 63^oC for 20 minutes [15].

2.5. Development of the Inoculum

The Sabouraud Dextrose Broth was used as medium for the development of the inoculum. Exactly 1.5g of the medium was dissolved in 50ml of distilled water. Exactly 10ml of the medium was dispensed into sterile universal bottle and was autoclaved and inoculated using 0.5 McFarland standard. This was incubated at room temperature for 48 hours [16]. A 0.5 McFarland was prepared where 1ml of concentrated sulphuric acid (H_2SO_4) was added to 99ml of distilled water in a beaker and was mixed well. In this way, a 1% v/v solution of H_2SO_4 was prepared. A solution of 0.5g di-hydrate barium chloride salt ($BaCl_2$. $2H_2O$) was dissolved in 50ml of distilled. In this way, a 1% w/v of $BaCl_2$ was prepared.

A solution of 0.6ml of $BaCl_2$ was added to 99.4ml of H_2SO_4 solution to make a 100ml. The solution was mixed well. This was the stock solution of the 0.5 McFarland turbidity standards. Exactly 2ml of the solution was transferred into capped tubes and stored at room temperature until use [17].

v/v = volume per volume

w/v= weight per volume

2.6. Fermentation of the Fruit Must

The fermenter was washed with detergent and rinsed with sterile distilled water. One (1) litre each of the pasteurized juice (must) was transferred aseptically to the fermenter. Exactly 0.3ml of sodium metabisulphide was added, and a mercury in glass bulb thermometer inserted at the top cover of the container. Exactly 3ml of the prepared inoculums using 0.5 McFarland standard was added to the must in the fermenter and was agitated to disperse evenly in the fermenter and kept at room temperature. It was aerated daily by stirring twice to encourage yeast multiplication. Specific gravity (S. G) was determined before and after fermentation. pH, temperature, %titratable acidity, % volatile acidity and yeast count of the must were determined before the fermentation started, and repeated after every six (6) hours for three days during the fermentation. Fermentation was terminated after three days and the wine was sieved to remove the shaft, bottled, pasteurized and the alcohol content was determined and the wine was divided into two. One was sweetened with sugar in the form of sucrose (wine B) and the other was not sweetened (wine A). The wines were refrigerated as described by [16].

2.7. Proximate and Physico Chemical Analysis of Must and Wines

The must and the wine produced were subjected to proximate analysis. These analyses include: moisture content, ash content, crude protein, fat content, total carbohydrate and total energy using the method described by [18]. The pH, temperature, total sugar, specific gravity, titrable acidity and volatile acidity of the must and wine were determined using standard methods reported by [16]. While percentage alcohol was determined using the method reported by [19].

2.8. Microbial Analysis of the Wine

2.8.1. Determination of Total Yeast Colony Count

Sabouraud dextrose agar supplemented with 50mg/L Chloramphenicol was used for selective enumeration of yeast. Serial dilution of the wine was carried out and inoculated using pour plate techniques. Pure culture was made on Sabouraud dextrose agar plates. Colonies from the plates of 10^{-6}dilution were counted using colony counter as described by [20, 21].

2.8.2. Bacterial Enumeration from the Wine

Nutrient agar was used for enumeration of bacteria. Serial dilution of the wine was carried out and inoculated using pour plate techniques. The plates were incubated at 37°C for 24 hours [16].

2.8.3. Total Coliform Bacteria from the Wine

MacConkey broth was used for the detection of coliform bacteria by the multiple tube technique. The medium was distributed in 9ml quantities standard test tubes with inverted Durham tube and was autoclaved for 15 minutes at 121^0C. The wine was serially diluted. Exactly 25ml from each dilution was aseptically inoculated into triplicate of 225 ml sterile MacConkey broth in standard test tube and incubated for 48 hours at 37°C [16].

2.9. Sensory Evaluation of the Produced Wine

Sensory evaluation of the watermelon wine produced was carried out by 10 panellists. This was done in order to determine its acceptability. Sensory attributes that were evaluated include taste, aroma, colour, clarity and overall acceptability using seven point hedonic scales with 7 indicating extremely like and 1 indicating extremely dislike [16].

2.10. Statistical Analysis of Data

The data obtained were analyzed using one way analysis of variance (ANOVA) to determine the differences in the sensory attributes and t test was conducted on the physicochemical properties [16].

3. Results

3.1. Cultural and Biochemical Characteristics of Yeast Isolated from Palm Wine

Table 1 showed the cultural and biochemical characteristics of isolated yeast. The yeast was characterized as *Saccharomyces cerevisiae* which fermented glucose, maltose and sucrose. It has bud and is circular in shape.

Table 1. *Cultural and Biochemical Characteristics of Yeast Isolated from Palm wine.*

ISOLATE	Morphological Characteristics				Biochemical Characteristics						
	Shape	Elevation	Pigmentation	Bud	FRU	GLU	LAC	MAL	MAN	SUC	Probable ORGANISM
PW4	Circular	Flat	Creamy	+	-	+	-	+	-	+	*Saccharomyces cerevisiae*
PW5	Circular	Flat	Creamy	-	-	+	-	+	-	+	*Saccharomyces cerevisiae*

Key: FRU = fructose, GLU = glucose, LAC = lactose, MAL = maltose, MAN = mannitol, SUC = sucrose, + = growth or colour change produced, - = no growth or colour produced

3.2. Biochemical Identification of Yeast Using Analytical Profile Index (API)

Table 2 showed the biochemical identification of yeast using analytical profile index (API). The yeast was identified as *Saccharomyces cerevisiae* which utilized glucose, galactose, N- Acetyle D- Glucosamine, saccharose and raffinose.

Table 2. *Biochemical Identification of Yeast Using Analytical Profile Index.*

Sugar (Carbohydrate)	Hr	SUBSTRATES									
		0	GLU	GLY	2KG	ARA	XYL	ADO	XLT	GAL	INO
Sugar Utilization	48 Hr.	-	+	-	-	-	-	-	-	+	-
	72 Hr.	-	+	--	-	-	-	--	-	+	-

Table 2. *Continue.*

Sugar (Carbohydrate)	Hr	SUBSTRATES									
		SOR	MDG	NAG	CEL	LAC	MAL	SAC	TRE	MLZ	RAF
Sugar Utilization	48Hr.	-	-	+	-	-	-	+	-	-	+
	72Hr.	--	-	+	-	-	-	+	-	-	+

Key: 0: Control, GLU: Glucose, GLY: Glycerol, 2KG: 2-Ketoglutanate, ARA: Arabinose, XLY: D- Xylose, ADO: Adonitol, XLT: Xylitol, GAL: Galactose, INO: Inositol, SOR: Sorbitol, MDG: A Methyl-D Glucose, NAG: N- Acetyl D- Glucosamine, CEL: Celiobiose, LAC: Lactose, MAL: Maltose, SAC: Saccharose, TRE: Trehalose, MLZ: Melezitose, RAF: Raffinose, +: Positive, -: Negative

3.3. Ethanol Tolerance Test of Saccharomyces Cerevisiae from Palm Wine

The result of the ethanol tolerance of the isolated yeast is presented in table 3. *Saccharomyces cerevisiae* showed positive tolerance to ethanol at 2%, 4%, 6%, and 8%.

Table 3. *Ethanol Tolerance Test of Yeast Isolated from Palm Wine.*

Isolate	Incubation period (hours)	Percentage Ethanol (%) 2 4 6 8 10 12 14 16							
Saccharomyces cerevisiae	48	+	+	+	+	-	-	-	-
	72	+	+	+	+	-	-	-	-

Key: +: growth, -: no growth

3.4. Variation in Temperature and pH of the Wine During Fermentation with Saccharomyces Cerevisiae

Figure 1 showed the variation in temperature of the wine during fermentation at interval of 6 hours until the fermentation was arrested. The temperature of wine increases within the first two days (from 25°C to 29°C) of fermentation and this declined (from 29°C to 28°C) towards the end of fermentation period. The control remained constant throughout the period of fermentation process. Figure 2 showed the result of variation in pH of the wine during fermentation at intervals of 6 hours. The pH showed a gradual decline (4.90 to 4.23) up to the 72 hours of fermentation. The control remained constant throughout the period of fermentation process.

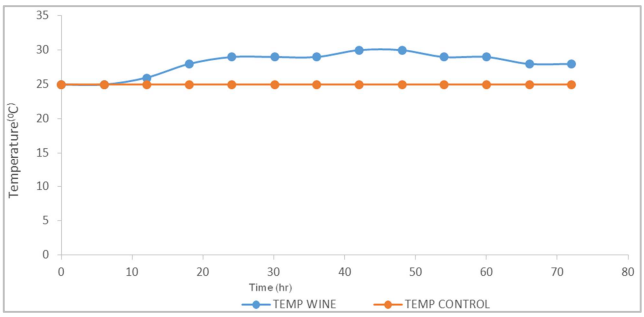

Figure 1. *Variation in Temperature of the Wine during Fermentation with Saccharomyces cerevisiae.*

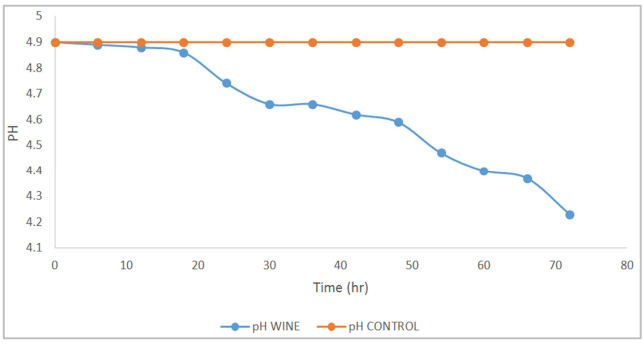

Figure 2. *Variation in pH of the Wine during Fermentation with Saccharomyces cerevisiae.*

3.5. Variation in Total Titrable Acidity of the Wine During Fermentation with Saccharomyces Cerevisiae

Figure 3 showed the result of variation in total titrable acidity of the wine during fermentation at interval of 6 hours. The titrable acidity showed a gradual increase (0.015 to 0.060) up to the third day of fermentation. The control remained constant throughout the period of fermentation process.

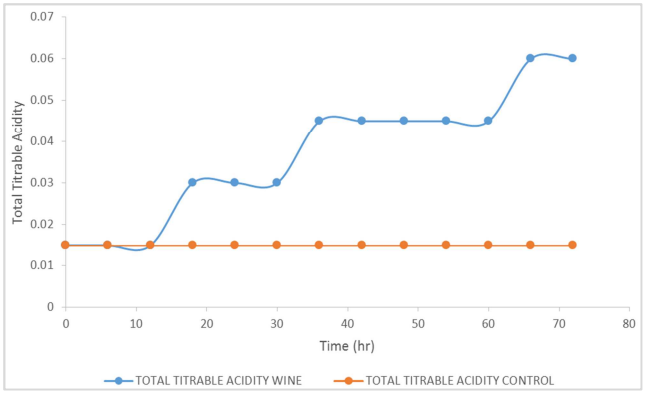

Figure 3. *Variation in Total Titrable Acidity of the Wine during Fermentation with Saccharomyces cerevisiae.*

3.6. Variation in Volatile Acidity of the Wine During Fermentation with Saccharomyces Cerevisiae

The result of variation in volatile acidity of the wine during fermentation is showed in figure 4. There was a gradual decrease (0.18 to 0.06) in volatile acidity up to the end of fermentation period. The control remained constant throughout the period of fermentation process.

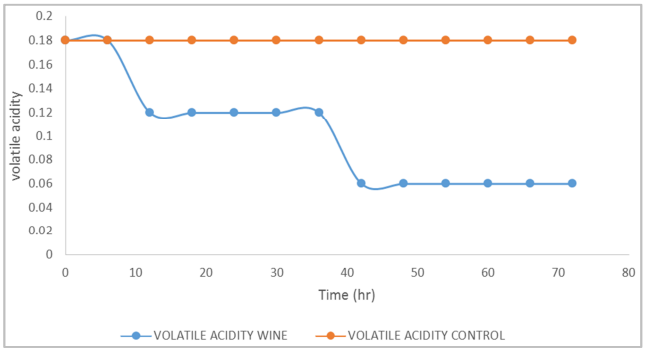

Figure 4. *Variation in Volatile Acidity of the Wine during Fermentation Saccharomyces cerevisiae.*

3.7. Variation in Total Viable Yeast Count of the Wine During Fermentation with Saccharomyces Cerevisiae

Variation in total viable yeast count of the wine during fermentation was observed and the result represented in figure 5. The total yeast count ranged between 1.9 - 8.2 × 10^7CFU/mL. The result showed a gradual increase (1.9 to 8.2× 10^7CFU/mL) within two days of fermentation and a declined (8.2 to 5.0× 10^7CFU/mL) towards the end of fermentation. No growth was observed in the control.

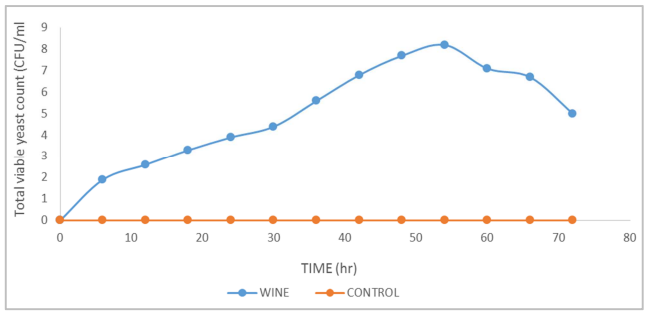

Figure 5. *Variation in Total Viable Yeast Count of the Wine during Fermentation with Saccharomyces cerevisiae.*

3.8. Physicochemical and Proximate Properties of the Must and Wine

Table 4 showed the results of physicochemical composition of the must (juice) and the wine. The must had a brix of 2.9220^{0}Brix but when fermentation was arrested on the third day, the brix was 0.5465^{0}Brix. There was significant difference at ($p< 0.05$) in the brix. The specific gravity was observed to decrease from 1.075 to 1.020 and a decrease in percentage sucrose from11% to 6% up to the third day of fermentation. The percentage alcohol was observed to be 7.36%. The results obtained from the proximate composition of the must and wine is presented in table 5. There was significant difference ($p< 0.05$) in the moisture, crude protein, carbohydrate and total energy except for percentage ash and fat. The moisture content obtained in this work was 70.94% and 98.40% for water melon and wine respectively. The ash content of the water melon fruit and wine obtained were 0.34% and 0.4% respectively. The fat content of the water melon fruit obtained was 0.035% and the carbohydrate content of the water melon fruit obtained was 27.81%.

Table 4. *Physicochemical Properties of the Must and Wine.*

Parameters	Brix (^{0}Brix)	Specific Gravity	Sucrose (%)	Alcohol (%)
MUST	2.9220±0.05	1.075	11±1.16	0
WINE	0.5465±0.01	1.020	6±1.15	7.36
P-value	0.000s	0.243ns	0.163ns	0.00s

Key: S: Significant, ns: not significant

Table 5. *Proximate Composition of the Water Melon Must and Wine.*

Parameters	Moisture (%)	Ash (%)	Crude Protein (%)	Fat (%)	Carbohydrate (%)	Total energy (Kcal/g)
WM	70.94±0.58	0.34±0.01	0.88±0.03	0.035±0.01	27.81±0.57	115.08
WMW	98.4±0.52	0.4±0.01	0.7±0.03	0.00±0.00	0.5±0.06	56.32
P-value	0.00s	0.12ns	0.04s	0.04s	0.00s	0.00s

Key: WM = Water Melon, WMW = Water Melon Wine, ns = not significant, s = significant

3.9. Microbial Analysis of the Produced Wine

The result of microbial analysis is shown in table 6. The result revealed the microbial quality of the wine. The microbial analysis of the wine revealed that there was no bacterial and coliform growth while the total viable yeast count ranged between 1.9 - 8.2 × 10^7CFU/ml before pasteurization and no count was recorded after pasteurization.

Table 6. *Microbial Analysis of the Produced Wine.*

Time (hr.)	Bacteria (CFU/ml)	Coliform (CFU/ml)	Yeast (CFU/ml) $\times 10^7$
0	-	-	-
6	-	-	1.9
12	-	-	2.6
18	-	-	3.3
24	-	-	3.9
30	-	-	4.4
36	-	-	5.6
42	-	-	6.8
48	-	-	7.7
54	-	-	8.2
60	-	-	7.1
66	-	-	6.7
72	-	-	5.0

3.10. Sensory Evaluation Score of the Produced Wine

The responses of the sensory evaluation from the panelists who tested the wine are presented in table 7. The means recorded for wine A (unsweetened wine) are 5.8, 5.7, 5.2, 4.8 and 3.9 for colour, acceptance, clarity, aroma and taste respectively. The means for the five evaluated attributes were recorded, where taste and acceptance achieved high value, followed by clarity, colour and aroma, with respective scores of 6.1, 6.1, 5.9, 5.8 and 5.6 for wine B (sweetened wine).

Table 7. *Sensory Evaluation of the Produced Wine.*

Panelist	Taste		Aroma		Colour		Clarity		Acceptance	
	Wine A	Wine B	Wine A	Wine B	Wine A	Wine B	Wine A	Wine B	Wine A	Wine B
P1	6	6	7	7	6	6	6	6	6	7
P2	6	7	5	6	6	5	6	6	7	7
P3	4	7	7	7	6	5	4	7	7	7
P4	2	5	3	4	5	5	4	4	3	5
P5	1	5	4	5	7	7	5	5	4	6
P6	6	7	5	6	7	6	6	7	6	7
P7	4	6	4	6	5	6	5	6	5	6
P8	3	6	4	5	6	7	6	6	7	5
P9	3	6	4	5	6	7	6	6	7	5
P10	4	6	5	5	4	6	4	6	5	6
Mean	3.9	6.1	4.8	5.6	5.8	5.8	5.2	5.9	5.7	6.1

Key: P= Panellist, Wine A= Unsweetened Water Melon Wine, Wine B= Sweetened Water Melon Wine

4. Discussion

Pure culture of *Saccharomyces cervisiae* isolated from palm wine was identified using morphological, biochemical and API characteristics. This result is consistent with the work of [22] who also isolated and identified *Saccharomyces cerevisiae* from fresh palm wine along with other yeast species and found it potent for use in wine making. A total of 19 yeasts were isolated but only 5 isolates were suspected to have the same colony morphology as *Saccharomyces cervisiae* after microscopy. The isolates assimilated mainly glucose, maltose and sucrose, but not fructose, lactose and mannitol. By reference to [23], they were suspected to be *Saccharomyces cervisiae*. They were tentatively identified as *Saccharomyces cervisiae* based on the API database. This is similar to the work of [24] that also isolated and identified *Saccharomyces cervisiae* from palm wine.

Ethanol tolerance is a unique property of the yeast (*Saccharomyces cerevisiae*) that makes it exploitable for industrial applications as stated by [22]. The yeast was able to grow in a medium containing 8% (v/v) of ethanol. This implies that this yeast strain can remain metabolically active in the fermentation medium and tolerate up to 8 % alcohol produce during the fermentation period. The maximum ethanol tolerance by the yeast in the study did not agree with the findings of [22] who found higher ethanol tolerance of 14.7% in their study on properties of palm wine yeast and its performance in wine making.

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. Water melon was used to produce fruit wine using *Saccharomyces cerevisiae* isolated from palm wine. The fruit juice provided all the nutrients necessary in the completion of the fermentation by *Saccharomyces cerevisiae*, hence the fermenting must was not induced with any artificial nutrient. The result of this work correlates with [25] that fermented water melon, banana and pineapple; and obtained quality wine product.

The results of the proximate composition showed level of significance between variables. There was significance difference ($p< 0.05$) in the moisture, crude protein and

carbohydrate content except for percentage ash and fat. It was observed that the moisture content of the fruit was high. This accounts for its high perishable nature and its short shelf life under normal storage condition. A similar observation was reported by [26]. 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 [26]. A minimal amount of ash was obtained. This indicates the presence of mineral component in the fruit and wine. This is in contrast with the reports by [27] who found reported 0.5% of ash content. Minimal amount of fat was obtained in the water melon fruit. This indicates that the fruit contains low level of fat. There was absence of fat after fermentation of the must. This suggests that the wine could provide protection against excess body lipids (cholesterol) and it demonstrate the desirable nutritive quality of the fruit wine produced as reported by [28]. The protein content of the water melon fruit obtained was low, and this is a probable indication that fear of over accumulation due to consumption of the fruits do not arise as reported by [29]. There was a decrease in protein content after fermentation with the fruit. Low protein content of the wine is good for maintenance of cellular organization as reported by [28]. 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. A similar observation was reported by [30].

Fermentation resulted in increase in temperature. This might be due to the catabolic processes of sugars by *Saccharomyces cerevisiae* cells resulting in metabolic heat that ultimately increased the temperature. A similar observation was reported by [22]. Fluctuations in temperature of the must were also observed during the period of fermentation. This fluctuation could be as a result of biochemical changes occurring during the metabolism of the substrate by the fermenting organism. A similar observation has been reported by [31]; in their study on production of mixed fruit (pawpaw, banana and watermelon) wine using *Saccharomyces cerevisiae* isolated from palm wine. Another observation has been reported by [32], in their study on pineapple and orange wine.

The study revealed that there was a continuous drop in pH values in the fruit wine as fermentation progressed. Studies have shown that during fermentation of fruits, low pH is inhibitory to the growth of spoilage organisms but create conducive environment for the growth of desirable organisms. This is attributed to the yeast metabolism during fermentation. A similar observation was stated by [32]. There exists a correlation between pH and acidity of the wine. The higher the acidity, the lower the pH of the wine. This is attributable to the acidification of the medium during fermentation. This is consistent with the work of [30]. Another study conducted by [16] on water melon and pawpaw wine also revealed a similar observation. The observed low pH underscores the ability of pure strain of *Sacchromycescerevisiae* from palm wine to yield alcohol at acceptable levels in fruit wine production as reported by [11].

It was observed that the acidity of fruit wine is dependent upon a number of factors like type of fruit, method of preparation and type of yeast used. Similar observation was reported by [33]. The study revealed an increase in total titrable acidity of the fruit wine throughout the period of fermentation. This increase in titrable acidity could be due to the conversion of organic acids to lactic acids and carbon dioxide. Similar observation was stated by [27]. It was observed that during fermentation of fruits, high acidity is known to give fermenting yeast competitive advantage in natural environments. This is similar to the studies by [32]. Acidity plays a vital role in determining wine quality by aiding the fermentation process and enhancing the overall characteristics and balance of the wine as stated by [28]. Lack of acidity might result to the production of a poor fermentation process. This corroborates [28].

The change in volatile acidity of the wine during fermentation was assayed for quality of the wine. The volatile acidity of the wine exhibited decreasing trends throughout the period of fermentation. This is in contrast with the result of [34] who found increasing trends of volatile acidity in the fermentation of mahua flowers. The volatile acidity started decreasing at 6 hours of fermentation up to the end of fermentation. Volatile acidity may result from the coupled oxidation of wine phenolics to yield peroxide which in turn oxidized ethanol to acetaldehyde and subsequently to acetic acid as reported by [34].

The brix of the fruit wine was observed to be decreasing. The decrease in the brix was predicted since it served as the major source of nutrients for the fermenting yeast. The fall in Brix at the end of the fermentation period was indicative of the amount of sugar concentration that has been removed from the juice by the fermenting organism. This is in consistent with the work of [22]. The result revealed that the total sugar content of the wine in the present study is less than 1 %. This is an indication that the wine will have a good keeping quality since the fear of further fermentation during storage which could lead to spoilage will not arise. This result also showed that the wine could be classified as dry table wines because of low total sugar content of less than 1 % as reported by [31].

The specific gravity of the fruit wine produced was observed to be decreased. This decrease might be due to the type of yeast used in the wine production. *Saccharomyces cerevisiae* isolated from palm wine has been reported by [26] to reduce specific gravity of fruit wines during fermentation. The observed reduction in specific gravity of the wine and the resultant increase in the alcohol concentration showed the efficiency of the *Saccharomyces cerevisiae* isolated from palm wine and implies that the yeasts is alcohol tolerant. Similar observation was reported by [11].

The alcohol content of the fermenting must increased during fermentation. The increase in the alcohol content can be attributed to yeast metabolism by continuous utilization of the sugar content, ethanol is produced and thus there is an increase in the alcohol content of the fermenting must, this

continued until all the available sugar in the fermenting must has been utilized. This result is in consistent with the work of [30]. The final alcohol content of the wine (7.36%) ranks it among table wines. This agrees with the findings of [35] who reported that wines that has 7 -14% of alcohol are considered as table wine. The ethanol content in wine is influenced by method of wine preparation, type of yeast used and initial total soluble solids in must as reported by [35]. In general, the percentage alcohol produced from the fruit used for the fermentation by the yeast strain was above 2% which is comparable with moderate grape wine as reported by [26]. The yield of alcohol might be attributed to the ability of *Saccharomyces cerevisiae* to break down the fermentable sugars in the must. This characteristic of *Saccharomyces cerevisiae* has also been effectively employed in the production of mixed fruit wine from pawpaw, banana and water melon by [31].

The yeast viable count of this study showed rapid increase in number of yeast cells during the first few hours (54hours) of fermentation and thereafter a decline. This increase in the number of yeast cell can be attributed to the effective utilization of the available sugar component and the daily aeration of the fermenting must leading to their cell propagation and rapid multiplication. This agrees with the findings of [30]. Decline in the number of yeast cells in the fermenting must might be due to the notable 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 while increase in the alcohol content recorded will also affect the rate of yeast growth, this can be corroborate by [36].

Result of microbial analysis revealed that there was no microbial contamination of the wine. This revealed the quality of the wine and implies that the wine was produced under hygienic conditions and is safe for human consumption. A similar observation was reported by [16]. Fermentation was carried out under aseptic conditions in order to obtain a good fermentation yield and establish the stability of the whole fermentation process throughout the period. These precautions or measures may have been the reason why there were no contaminants in the fermentation medium. The heat treatment (pasteurization) might also be another reason why there was no contaminant. This means that the heat treatment was sufficient to destroy microbial contaminant in the wine. This is similar to the reports given by [16].

Sensory evaluation rated the wine acceptable with wine B> wine A. Wine B recorded more scores in all the parameters tested except in colour where the mean scores were the same. A similar observation was reported by [31]. The mean score for colour by the panel was the same. This could be due to the presence of lycopene which gives water melon its natural colour as reported by [13].

5. Conclusion

In conclusion, this study revealed that palm wine is an excellent habitat where *Saccharomyces cerevisiae* can be isolated and this *Saccharomyces cerevisiae* has brewing potential. The result also confirmed that a tropically available fruit in Nigeria like water melon is suitable for fruit wine production with good microbiological standard and high acceptability, taking into account the fact that the panelists were not familiar with the water melon wine. For this successful fermentation, wine making should be encouraged commercially in Nigerian using our locally available fruits like water melon. This will earn income and revenue for both our citizens and government, reduce dependency on foreign and imported wines, increase the income of local farmers that cultivate watermelon and grow our economy.

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