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Physico-Chemical Properties and Sensory Evaluation of Wine Produced from Tiger Nut (*Cyperus esculentus*)

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Abstract : Production of wine from sources other than grapes has gained popularity in recent years. Tiger nut (*Cyperus esculentus*) is a high-yielding, readily-available tuber which has lots of dietary and medicinal values with the attendant potentials of being processed to many other edible products. In this study, wine was produced from Tiger nut and the quality of the wine evaluated. Healthy tiger nutobtained from a market in Ebonyi State, Nigeria were washed with clean water and ground with an electric blender until a homogenous pulp was obtained. The pulp was filtered using a muslin cloth. A solution of sugar in water (200g in 70cm^3), 0.90g of Saccharomycescerevisiae (baker's yeast), ammonium phosphate (0.60g) and potassium phosphate (0.60g) were added and the mixture was allowed to ferment for 6 days (primary fermentation). The temperature, pH, specific gravity, total titrable acidity, and sugar level of the sample were determined after every 12 h. The wine was racked and allowed to ferment for 14 days (secondary fermentation). It was then left to clarify for three months. The clarified wine was left to mature for 6 months before the final physic-chemical and sensory evaluation were carried out. The results of the analysis revealed that tiger nut wine produced had 15.8% alcohol content, 0.68% total titrable acidity, specific gravity of 0.9522, a pH of 2.8 and 1.25% total sugar content. These values are comparable to those obtained for other fruit wines. The sensory evaluation revealed that the attributes of the wine were acceptable to the majority of the respondents.
Key words : Tiger nut, Tubers, Wine, Fermentation, Sensory evaluation, Alcoholic beverages.

Introduction

Wine is an alcoholic beverage made, traditionally, from fermented grapes. Unlike most food and beverages, wine has long shelf life and it is seldom a medium for disease vectors. At high concentration, alcohol in wine has antipathogenic effect[1]. Alcohol and acid in the wine act as inhibitors to bacterial growth, allowing the wine some years of shelf life [2]. Natural wines may exhibit a broad range of alcohol content, from below 9% to above 16% [3]. Grapes have the advantage of being fermented by yeast to ethanol without the addition of sugars, acids, enzymes or other nutrients [4][5]. Different varieties of grapes and strains of yeasts produce different styles 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. 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 [6].

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 flavors 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 [7] thereby improving the health benefits of the products. Strawberries, plums, watermelons, quince, apricot, apple, raspberries, bilberries, cherries blackberries [8], mango [9], sugar cane juice [10], peaches, gooseberries, boysenberries, grapefruits, pears, pineapples, persimmons are all very suitable for fruit home-made wine [11]. Some well known fruit wines are hard Cider from apples, Perry from pears, Pomegranate wine, Banana, Blueberry, Pumpkin and Elderberry wine [4].

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[2]. 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 nutrients needed to maintain fermentation, or a combination of these three characteristics. To obtain products of high phytochemical yield and sensory satisfaction, blends of fruits have been investigated. Wines made from blends of mango, jackfruit and pineapple [4];banana, pawpaw and watermelon [5]; apple and medicinal herbs [12] and pawpaw and pineapple [13] have been reported. Wines fermented from tuber extracts have also been reported[14]

The winemaking process typically begins with the crushing of fruits to release the must. The enzymes present in the must hydrolysemacromolecules into forms ready for use by yeast and bacterial cells. For instance, the action of pectic enzymes enables the release of cellular constituents in the must [15]. Subsequently, alcoholic fermentation may start spontaneously due to the indigenous yeasts derived from the fruit source or picked up from the crushing equipment, or by the inoculation of known strains of yeast.

In the absence of oxygen, yeasts act on the must to release the carboxylic carbon atom in the form of carbon dioxide and the remaining components become acetaldehyde which is eventually converted, by reduction, to ethanol (scheme 1). At the same time, some amount of acetaldehyde, a small amount is converted, by oxidation, to acetic acid [16].Numerous volatile compounds such as lower alcohols, volatile phenols, sulphur compound, esters and other carbonyl compounds which contribute to the pleasant aroma of the wine are also produced [17][18][19].

$$C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2$$

Scheme 1: fermentation of sugar to alcohol

Although yeast, lactic and acetic acid bacterial colonies naturally live on the surface of grapes[20], traditional wine makers prefer to control fermentation with predictable cultured yeast like Saccharomycescerevisiae. The use of different strains of yeasts contributes to the diversity of wine even with the same fruit [16]. Alternatively, non-Saccharomycescerevisiae yeasts are used in the industries to add greater complexity to wine [20].The function of the yeast stops either when all the sugar in must has been converted into other compounds or when the alcohol concentration is strong enough to halt its enzymatic activity [1]. Wine may be treated with malolactic bacteria to foster secondary fermentation. These bacteria are capable of decarboxylating malic acid to lactic acid and carbon dioxide with the aid of the malolactic enzyme [21].

The wine is then subjected to maturation process which aids the loss of yeasty odors, the dissipation of excess carbon dioxide, the precipitation of suspended materials and the changes in aroma [22]. Matured wine is racked to remove sediments formed during clarification [14]. It is then stabilized, filtered and bottled [22]. Ageing of bottled wines helps to further convert acetaldehyde to more useful or volatile compounds [23].

Tiger nut, Cyperus esculentus, is an annual or perennial plant which grows to about 90 cm tall, with solitary stems growing from a tuber (Plate 1). It is a highly adaptable crop which grows well under a wide range of climatic and soil conditions. It is native to the tropics, subtropics and warm temperature regions; though its history has been traced to Africa [24]. The tubers are about 0.3 cm in diameter and the colors vary between yellow, brown, and black [25]. One plant can produce several hundred to several thousand tubers during a single growing season. It is found wild, as weed, or cultivated as a crop [26] in Africa, South America, Europe and Asia (Spain). Tigernut is cultivated in African countries such as Niger, Nigeria, Ghana, Togo and some others including the Ivory Coast where it is made into a sweet meat, used uncooked as a side dish or exported to Spain [24]. In Nigeria, it is a common crop in Kano, Zamfara, Gombe, Katsina States where it is called 'Aya' [26]. It is usually eaten either fresh (Plate 3), as snacks or dried for preservation (Plate 2), and rehydrated before eating.



Plate 1: Tiger nut plant **Plate 2: Dried tiger nut tubers** **Plate 3: Fresh tiger nut tubers**

Tiger nut has been reported to be a "health" food, since its consumption can help prevent heart diseases and thrombosis [26]; and it is said to activate blood circulation and reduce the risk of colon cancer [27]. Tiger nut is used in the treatment of flatulence, diarrhea, dysentery, debility and indigestion [28]. It is rich in energy food (starch, fat, sugar, and protein), minerals (mainly phosphorus and potassium), and vitamins E and C. Tiger nut tubers contain almost twice the quantity of starch as potato or sweet potato tubers [26]. The oil of the tuber has been found to contain 18% saturated (palmitic acid and stearic acid) and 82% unsaturated (oleic acid and linoleic acid) fatty acids. The moderately high content of phytosterols further enriches the quality and value of tiger nut oil as a food source [29].

The tubers are edible and can be eaten fresh or as beverage. In Spain, tiger nut is used in making a beverage called horchata [26].Flour of roasted tiger nut is sometimes added to biscuits and other bakery products as well as in making oil and soap [30]. It is also used for the production of nougat, jam, beer, and as a flavoring agent in ice cream and in the preparation of a local beverage called kunnu [31]. To make up for the poor nutritional value of kunnu, a beverage prepared from cereals, tiger nut is added as food supplement. It is rich in high quality oil [29][30] that can be used naturally with salads or for deep frying. Tiger nut "milk" has been investigated as a replacement for milk in fermented products, such as yogurt production, and in the diet of people intolerant to lactose [26]. When used as antioxidant in the cosmetic industry tiger nut oil helps slow down the ageing of the body cells, improves the elasticity of the skin and reduces skin wrinkles [32].

There are few reports on the production of non-alcoholic wine using blends of sugarcane and tiger nut [33]. However, extensive literature search has not shown any report on the production of alcoholic wine using tiger nut; hence the novelty of the investigation. In this study, therefore, the production of wine using locally source tiger nut was investigated.

Materials and Methods

2.1 Materials

Materials used in this study are locally sourced tiger nut, Sugar, Distilled water, Ammonium phosphate, Potassium phosphate, Saccharomycescerevisiae (baker's yeast), White transparent bucket, Electric blender and Refractometer

2.2 Methods

i. Wine Production

Healthy tiger nuts were selected, washed with clean water and ground using an electric blending machine until a homogenous pulp was obtained. A muslin cloth was used to extract the juice by filtration. The extracted juice (must) was poured into a clean transparent plastic bucket and allowed to stand for about 3 h. A solution of sugar in water (200g in 70cm^3), 0.90g of Saccharomycescerevisiae (baker's yeast), ammonium phosphate (0.60g) and potassium phosphate (0.60g) were respectively added [5][7].

The primary fermentation of the must lasted for 6 days in an air-tight transparent plastic container. The mixture stirred vigorously, every 12 h, with subsequent reading of the temperature, pH, specific gravity, total titrable acidity, and sugar level (brix). After 6 days, the wine was racked into the secondary fermenter. The secondary fermentation was done in an air tight container from which a tube was passed into a transparent plastic bucket containing clean water. As fermentation progressed, air bubbles passed into the water through the tube and were used to monitor the course of fermentation. This was allowed for 14 days; when fermentation was assumed to have been completed which was evident from the absence of bubbles in the water container.

When fermentation stopped, the wine was promptly clarified, ensuring minimum exposure to oxygen. After secondary fermentation, the wine was also clarified. The clarification was done as described in a recent research report [5]using bentonite (a clarifying agent). Bentonite (125g) was dissolved in 500cm^3 of boiling water and stirred properly to a gel form. This was allowed to stand for 24 h. Then 40 g of the gel-like bentonite was transferred into the wine followed by stirring to dissolve properly. A small quantity of the mixture was collected in a clean bottle which was covered tightly and was used to monitor the process of clarification. After three months of clarification, the wine was filtered using muslin cloth, sieve and siphon tubes sterilized by 70 % alcohol. The wine was siphoned into the sieve containing four layers of muslin cloth. The residues were removed and the filtrates were allowed to mature for a period of 6 months before physico-chemical analysis was carried out.

Table1: Recipefor Tiger nut Wine Production

Ingredient	Tiger nut juice	Sugar solution	Saccharomycescerevisiae (baker's yeast)	$(NH_4)PO4$	K_3PO_4
Amount	5300cm^3	70cm^3	0.9g	0.6g	0.6g

2.3 Physico-chemical analysis

2.3.1 Total titrable acidity

The total titrable acidity of the wine was determined as described by Ogu [34]. Using phenolphthalein as indicator, 10cm^3 of the wine sample was measured into a conical flask and titrated against 0.1N solution of sodium hydroxide.The total titrable acidity was calculated as follows:

$$\text{Total titrable acidity (TTA)} = \frac{V^1 \times N \times 75 \times 100}{1000 \times V}$$

Where
V^1 = Volume (cm^3) of NaOH
V = Volume (cm^3) of sample used
N = Normality of NaOH

2.3.2 Alcohol content

The alcohol content of the wine was determined using psycnometer or saccharometer as described by Ogu [34], and calculated as follows:

Percentage alcohol = (OG – FG) x 0.575%
where
OG = Original Gravity of the sample
FG = Final Gravity of the sample

2.2.3 Total sugar content

The total sugar content (brix) was determined using a refractometer. This was done by placing about 3 drops of the must or wine sample on top of the prism assembly and then closed with the daylight plate. The sample was then allowed to stand for approximately 30 seconds for it to adjust to the temperature of the refractometer. Then the result was taken by reading the calibrations of the refractometer through the eyepiece.

2.3.4 Specific gravity, pH and Temperature

The specific gravities of the wines were determined using the hydrometer and the results were determined from the reading on the stem [5]. The pH and temperature were also determined using a calibrated digital (HANNA) pH meter and an analytical thermometer respectively.

2.4 Sensory evaluation

The wine was evaluated by panel tastings. Thirty judges,from Department of Food Science and Technology, Ebonyi State University, Abakaliki participated in the experiment. Their selection was based on interest as well as their experience in wine sensory analysis. The panelists were first trained to familiarise them with the triangle test or a duo-trio test[35] for wine tactile, taste and odour. Aqueous solutions of Sucrose (10 g/L), Tartaric acid (0.5 g/L), Sodium chloride (2 g/L), Quinine sulphate (6 mg/L),Monosodium L-glutamate (0,6 g/L) and tannic acid (1.0 g/L) were used to set five basic tastes for sweet, sour, salty, umami, bitter and astringency respectively[35]. Samples were assessed one after the other in comparison to a sample of potable water. Variations in taste intensity depend on the concentration of the stimulus in the test sample, and were detected based on already established suprathreshold level (Table 2). All the judges identified taste and odour of the wine sample and rated the intensities of the stimulus using a 0-5 point hedonic scale.

Table 2 : Examples of solutions which can be used for tests to discriminate between intensity levels of astimulus

Solution used to detect stimulus	**Supratheshold concentration**				
Odour discrimination	1	2	3	4	5
Acetic acid solution	0.10g/L	0.30g/L	0.50g/L	0.70g/L	0.90g/L
2,4,6 trichloroanisole (TCA) solution	1ng/L	3ng/L	5ng/L	7ng/L	9ng/L
Ethyl acetate solution	10mg/L	40mg/L	70mg/L	100mg/L	130mg/L
4 Ethylphenol solution	0.05mg/L	0.15mg/L	0.30mg/L	0.45mg/L	0.60mg/L
Taste discrimination					
Sucrose solution	2g/L	6g/L	10g/L	14g/L	18g/L
Tartaric acid solution	0.25g/L	0.50g/L	0.75g/L	1.0g/L	1.25g/L
Sodium chloride solution	0.5mg/L	2.0mg/L	3.5mg/L	5.0mg/L	6.5mg/L
Quinine sulphate solution	0.5mg/L	2.5mg/L	4.5mg/L	6.5mg/L	8.5mg/L
Monosodium L-glutanate	0.05g/L	0.3g/L	0.6g/L	0.9g/L	1.19/L
Astringency discrimination					
Tannic acid	0.5g/L	0.75g/L	1g/L	1.25g/L	1.5/L

Results

The changes observed in the physic-chemical properties of the wine during fermentation are presented in Table 3 and Fig. 1. Properties and the hedonistic grading of the finished product are presented in Fig.2 and Table 5 respectively.

Table 3: changes in tiger nut physicochemical properties with time

Time (days)	**pH**	**Temp (^oC)**	**Sp.gravity (g/cm^3)**	**TTA (%)**	**Alcohol cont.(%)**	**Brix (%)**
1	3.79	26.00	0.9926	0.43	4.30	4
2	3.72	27.60	0.9923	0.56	8.86	3.80
3	3.66	29.00	0.9918	0.59	12.97	3.50
4	3.02	28.30	0.9902	0.61	15.01	2.60
5	2.87	27.20	0.9895	0.65	15.30	2.00
6	2.80	27.00	0.9878	0.68	15.50	1.25

Table 4: Physico-chemical properties of final product

Properties	Alcohol (%)	TTA (%)	Residual acidity (%)	Volatile acidity (%)	Sp. Gravity (g/cm^3)	Total sugar (%)	pH
Content	15.8	0.68	0.40	0.28	0.9522	1.25	2.8

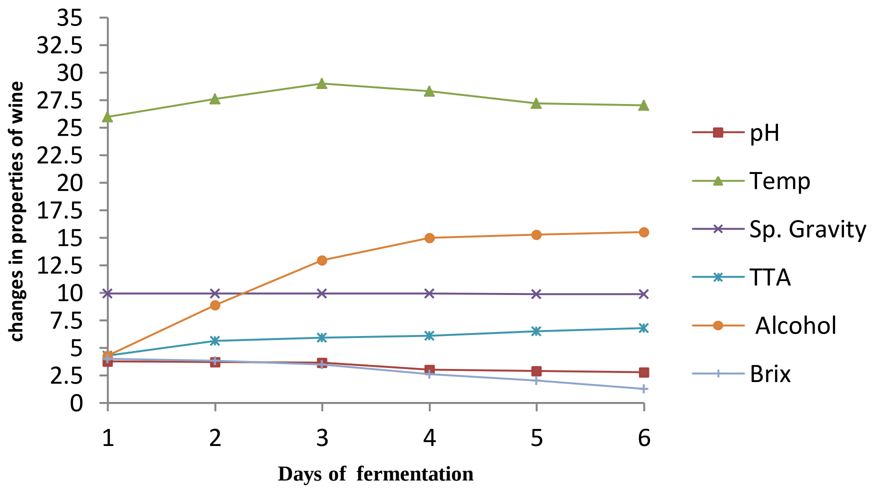

Fig. 1: Plots of tiger nut wine physicochemical properties versus time

Table 5: Summary of sensory evaluation

Grade	Excellent	Very good	Good	Fair	Neutral	Poor
Grade point	5	4	3	2	1	0
No of respondents	12	8	5	2	2	1
Percentage of points	40	26.67	16.67	6.67	6.67	3.33

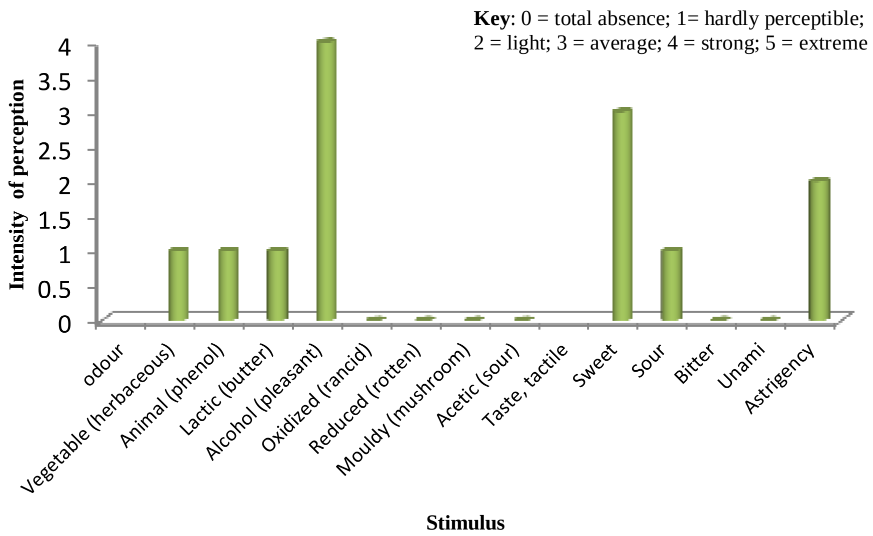

Fig. 2: Olfactory, tactile and taste characteristics of tiger nut wine

Discussion

It has been established from research findings [2] that the ease of wine production and the variety in quality of wine depend much on the phytochemicals inherent in the must, the performance of yeast used in the fermentation and the process adopted. The same yeast strains behave differently in different must because there is the need for yeast strains to adapt to different environments, such as sugar composition and concentration of acetic acid [36][37][38]. The fluctuations in temperature of the wine sample (Table 2), observed during the period of fermentation, could be as a result of biochemical changes occurring during the metabolism of the substrates by the fermenting organism. The temperature of the wine, during fermentation, fluctuated through 26, 29 to 27 °C (Table 3). The fluctuation was a function of the alcohol content and the acidity of the wine which influenced the activity of the yeast as well as the heat generated in the process [1][2]. There was also decrease in the specific gravity of the must during primary fermentation (Fig 1). The continuous decrease is attributed to the uptake of sugar by the yeast which leads to the formation of the less dense alcohol and carbon (iv) oxide.

In the case of change in the pH during primary fermentation, Fig 1 shows that there was a gradual decrease in pH value for the wine sample. This could be ascribed to increase in the production of organic acids as the fermentation progressed [34]. Similar observations have been reported for sweet potato wine [14].Apart from being inhibitory to spoilage organisms, low pH also gives fermenting yeasts a competitive advantage in natural environment [37][39].It therefore indicates that tiger nut wine has a shelf life.

Throughout the period of primary fermentation, a consistent increase in the total acidity of the winewas recorded as shown in (Table 3). The increase in total titrable acidity during primary fermentation is, undoubtedly, as a result of increase in the production of organic acids. An earlier investigation [37] has reported that the total acidity of final wine should fall within the range of 0.5 and 1.0 %. The result of this study reveals that the value of total acidity (0.97%) is within this range. This value is consistent with the reports of 0.35 ± 0.02 to 0.88 ± 0.01 %for mixed banana, pawpaw and watermelon fruit wine [5] and 0.15 ± 0.07 g/100cm^{3}for bael wine [39]. However, it is lower than the report1.34g/100cm^3 for sweet potato wine [14]. The observed acidity is more of volatile acidity than the residual acidity (Table 4) which is a good phenomenon. Volatile acids can easily be removed from the body system through perspiration [5] and consequently have less harmful effect than the residual acids.

Inadequate sugar content and low level of acidity have been reported as the major problems associated with making non-grape wine[5][13][40]. In order to supplement the sugar content of the musts, a sugar solution was added. The total sugar content of tiger nut wine decreased in the course of fermentation (Fig 1). Upon completion of fermentation,the wine recorded total sugar content of 1.25% (Table 4). This valueis higher than the report [5] for banana, pawpaw and water melon wine. It is however in the same range with the reportsfor sapota fruit wine (3.28g/100cm^3) [41], potato wine (1.35g/100cm^3) [14], and bael wine (2.05 ± 0.12 g/100 cm^3)[39]. Since the total sugar content of tiger nut wine is not more than 9%, it implies that it is a dry table wine [42][43].

Conversion of sugar to alcohol is the hub of wine making. In this investigation, the wine sample recorded an appreciable concentration of alcohol (15.8%) which is a mark of good quality. This value is appreciably higher than 10.45% reported [37] for potato wine. It is not surprising since documented evidence [26] has shown that tiger nut has a high concentration of fermentable sugar and the yeast (S. cerevisiae) is a known high performance species. However, the alcohol content of tiger nut in this study is below the value reported [5] for a blend of banana, pawpaw and watermelon fruit wine (16.00-18.50%). High alcohol content has been reported as a factor of good quality wine since alcohols are important precursors for the formation of esters and other carbonyl compounds necessary in wine making [5][38]. This implies that the concentration of ethanol affects the whole characteristic quality and flavour of the finished product.

Tiger nut wine investigated was observed to have cream colour. The olfactory characteristics of the wine (Fig. 2) show that tiger nut wine emits high level of pleasant aroma. This could be attributed to the high alcohol content which serves as a starter for esters and other carbonyl compounds [5]. These attributes compared favourably with the reports for tropical fruit wines [5][14][39][41][44]. In the same vein, the taste and tactile properties of tiger nut wine (Fig. 2) reveal that it has appreciable sweet taste and low level of astringency. It is evident from Table 5 that 40% of the respondents rated the wine as excellent, 26.67% and 16.67% rated it as very good and good respectively while 16.67% rated it either as fair, neutral or poor. In summary, sensory evaluation revealed that 25 out of 30 judges accepted the qualities of the produced tiger nut wine; and this represents more than 83% of the number of respondents.

Conclusion

Considering the determined quality parameters for wine produced from tiger nut, it may be inferred that tiger nut can be used to produce good quality wine. The physicochemical and sensory attributes of the wine were acceptable to the consumers and comparable to already published studies. Apart from other high nutritional value, the main advantage of using tiger nut in wine making is that since its must contains high sugar content, less amount of sugar is needed to augment the sugar level. By understanding a few basic wine making principals, this readily available tuber can easily be turned into value-added wine that can stand the test of time. Wine making using tiger nut can open new doors to producers of wine who have limited access to grape and other easily fermentable fruits. With good choice of yeast species and improved technology, the quality of tiger nut wine can be said to be comparable to fruit wine.

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