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Palm Wine: A Review on Its Composition, Preservation, Health Benefits, and Market Value

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Abstract

Numerous people in sub-Saharan Africa, Asia, India, and Mexico enjoy palm wine, a traditional alcoholic beverage made from the sap of various palm plants. Its colouring is pale, and its flavours run the gamut from sweet to sour and vinegary. For people who live in cities and villages, tapping the palm tree to get the beverage is an important source of income. Although the alcohol concentration of fresh palm wine is low and it is sweet, it gradually rises through fermentation. It is used for numerous purposes, most notably for medicine, weddings, and traditional naming rituals. They are suitable for improving vision since they contain vital microbes like yeast as well as nutritionally significant ingredients like amino acids, proteins, vitamins, minerals, sugars, alcohols, and water. Jaundice, smallpox, chicken pox, measles, and malaria have all reportedly been treated with palm wine. Additionally, palm wine assists nursing mothers produce more milk in addition to its reputed antioxidant qualities. The purpose of this study is to review palm sap/wine, its preservation, applications, biochemical components, odorants, microbiota, nutrient content, and health effects. It also conducts an economic analysis of the palm wine market and traditional fermentation and distillation of raphia palm sap for ethanol production

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Introduction

Palm wine is a traditional alcoholic beverage popular in sub-Saharan Africa that is made from the palm sap of various palm trees (Amadi, 2022; Ojo and Agboola, 2019; Falegan and Akoja, 2014). Palm wine is the sap fermented from the Raphia palm (*Raphia hookeri*) and oil palm (*Elaeis guineensis)*. It is thought that the two species originated in West African marshes. Oil palm wine (OPW) is the name given to the wine produced by oil palm trees, whereas raphia palm wine (RPW) is the name given to the wine produced by raphia palm trees (Nwankwo, 2019; Ikegwu, 2014). The ideal ecological condition for the Raphia palm is the tropical rainforest (Agambi *et al.*, 2017; Ugwu and Igboeli, 2009; Ndom, 2003). *R. hookeri* is hapazanthic i.e. after a period of growth of the vegetation; flowers and fruits are produced only once and die. The flower is signaled by the simultaneous appearance in the crown of more than one expanded 'spear' leaves. The palm is tapped for wine (sap) at this stage. One of the most important occupational engagements of the rural inhabitants in the Nigerian palm belt is the production of palm wine (Djeni *et al.*, 2020). Palm wine shelf life is relatively short and can be ameliorated by refrigeration. However, plant parts such as leaves, stem barks and roots have been discovered and used locally and traditionally by the palm wine tappers to preserve palm wine. The bark of *Saccoglottis gusonensis* (known as "nche" in Igbo land) has been identified as a comparatively effective local preservative. Although, with or without this preservative, palm wine is still said to be best consumed within forty-eight (48) hours (Uloneme *et al.*, 2014). Palm wine has several social-economic, medical, religious and nutritional uses which have increasingly enhanced the popularity and demand for this natural product. The wine is rich in such nutrients as sugars, proteins, amino acids, vitamins and minerals. Its residue (dregs) is rich in a dense population of yeasts which are claimed medically to improve eyesight (Agwuna *et al.*, 2019; Agambi *et al.*, 2017; Augustine *et al.*, 2013; Bohoua, 2008). The presence of glucose, fructose, and raffinose in palm wine has been reported at various concentrations during palm wine fermentation (Uloneme *et al.*, 2014). Both men and women usually enjoy the consumption of palm wine an alcoholic beverage with good nutritional values. The production and trade of palm wine represents a significant source of income in West Africa because it employs almost

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75 percent of the male population in some villages, produces about 10,000 L per day, and generates a per capita income of between US$40 and US$7014 per month (Djeni *et al.*, 2020). The rate of absorption of palm wine is largely dependent on the palm wine concentration, presence of food in the stomach and gastric emptying rate, and is eliminated as urine from the body, breathing and perspiration (Uloneme *et al*, 2014).

The palm trees

The Palm trees significantly affect both the economy and the everyday life of millions of people around the world. It has contributed hugely to the world economy, the local economy and the lifestyle of the people. Surprisingly, the huge number of products can be gotten from these species and some of the food products are fruits, seeds, the 'palmito', honeys, 'sagu' (material with starch extracted from the centre of the trunks), different drinks obtained from the sap or the fruits, crystallized sugar from the sap, etc. Other products are oils, fibres and waxes. Palm trees contribute in these different ways as food, housing, furniture, energy, clothing and gardens (Rivas *et al*., 2012).

Raphia palm is found in Nigeria in the south-south geopolitical zone. It provides material for house construction, furniture, food, clothing, edible oil, etc. Economically, the raphia palm is one of the most useful palms. In Africa, the raphia palm leaves are the largest among the palms. It produces sap which is drunk by millions of people in Africa. The sap of the raphia palm has drawn the attention of researchers over the last decade. Consequently, the sap has been preserved. Nutrients that are beneficial to human health and which could play active roles in human physiology have been detected in the sap. Products have been developed from the sap, which could be rehydrated and drunk like the original sap. The products could also be used as sweeteners in the preparation of food. Every part of the palm is useful; thus, its increased cultivation could provide a good income for small, medium and large-scale farmers, (Obahiagbon, 2009).

Origin and taxonomy

Palisot de Beauvois (1906) was the first to give the name Raphia to palms bearing the type of fruits described by Gaertner (1989) as reported by Ndom (2003). Mann and Wendland (1864) after a-four-year research work along the West African coast , presented five species of Raphia palms, which included *Raphia hookeri*. Others are *R.africana, R. sudanica, R. vinifera,* and *R. farinifera*. Raphia. Palm taxonomy had been said to be awkward because of its large trunk and leaves being the greatest in the plant kingdom (Russel, 1965). The Raphia palm is a tropical tree crop that needs lots of rain, hot weather, high relative humidity, and long sun exposure hours to thrive properly (Ndon, 2003).

Palm wine tapping

The process known as "Palm Wine Tapping" is used to obtain palm wine from the palm tree (Lasekan *et al.*, 2007). "Palm wine Tappers" are persons who tap palm trees for their juice. A standard "palm wine tapper" should have a gallon, a grappling rope, a small cutlass for slicing palm fronds, and a tapping blade.

Ogbulie et al. (2007) indicate in their statement that palm wine tapping entails removing the palm fronds to expose the sensitive tissues at the highest point of the palm tree. The "tapping blade" is used to pierce a hole into the tissue so that the palm wine can escape. To transfer the wine to the gallon, gaps are connected with specially shaped small bamboo, empty copper tube, or other devices. If the palm tree was still standing, the gallon could be secured to it with a rope. If the palm tree had been felled, the gallon would merely be supported by sticks. Thus, in West Africa, the collection of palm sap has traditionally been done using both destructive and non-destructive techniques (palm wine tapping from the inflorescence and incision on the apical meristem or trunk of the felled palm tree, respectively) (Djeni et al., 2020). The destructive palm wine tapping procedure is drilling holes or creating cavities in the fragile apical meristem of the tree trunk to insert tubes or create spaces for sap to be collected in pots, traditionally made of calabash or terracotta clay, but more recently of plastic. When oil palm wine is being harvested, the tree is removed before harvesting. The tree will die during this procedure, and the region has reported significant devastation of the palm tree population as a result of excessive palm wine tapping (Babitseng and Teketay, 2013).

Palm sap/wine

Palm wine is a naturally fermented drink made from the sweet, alcoholic, and fizzy sap of several palm trees (Ojo and Agboola, 2019; Adebayo and Ajiboye, 2011; Obiahiagbon and Osagie, 2007) such as raphia palm (*Raphia hookeri*), oil palm (*Elaeis guineensis*), nipa palm (*Nypa fruticans*), palmyra or borassus palm (*Borassus flabellifer*), wild date palm (*Phoenix sylvestris*), etc. Unfortunately, palm wine is unstable (Augustine *et al*., 2013). It has a sweet flavour while it is fresh, but with time, this sweetness is lost as a result of the wine's natural microbes spontaneously

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fermenting its sugars into alcohol and then acetic acid. Palm wine has a characteristic tingling property which is as a result of gas effervescence from the fermentation of its sugar content (Augustine *et al*., 2013). However, several researches on the microbiology of palm wine have detected several bacteria and yeast flora to be involved in the process of fermentation (Augustine *et al*., 2013). The names of palm wine in different regions in Africa are given in Table 1.

Millions of people from southern Nigeria engage in the drinking of palm wine during social activities. About 20% of drinks produces by palm wine is contributed by the Raphia palms alone in its unfermented as well as fermented states, depending on the consumer choice (Obahiagbon and Osagie, 2007, Obahiagbon, 2009).

Palm wine preservation

Because of the significance of Raphia palm sap/wine in ceremonies like marriage, obituary, and for entertainment generally, attempts have been initiated to preserve the product but were not successful. Okafor (1975) investigated the efficacy of sodium metabisulphite, diethylpyrocarbonate (DEPC), and sorbic acid in the preservation of palm wine. From the studies, he concluded that sorbic acid was most suitable for the preservation of palm wine because of its wider spectrum of bactericidal action and its tolerance in fairly large quantities by man, despite its insolubility in palm wine and colour impartation. Because of the change in colour of palm wine from the normal white, this product was not accepted by the Nigerian populace. Another study was carried out by Esechie (1978) on palm wine preservation by using sodium metabisulphite, potassium sorbate and extract of *Saccoglottis gabonesis* followed by treatment by heat (pasteurization at 70ºC for 40 min). Fresh palm wine should only be pasteurised at 70°C for 40 minutes to preserve it for up to 9 months in all experiments.

In his research on the preservation of palm wine, Eapen (1982) suggested using sodium metabisulphite in addition to pasteurisation at 70°C for 40 minutes, although this approach was only able to keep the product fresh for a maximum of 12 months.

Raphia palm sap's shelf life was increased to 24 months by Obahiagbon and Oviasogie (2007) with pasteurisation at 75 °C for 45 minutes without the use of any chemical preservatives. At the end of the 24th month, the essential nutrients in the sap were all still present without degeneration. The health risks of food preservatives, such as the carcinogenic sodium metabisulphite that had been advocated for use in the preservation of palm wine for decades, have been eliminated by this method of preserving Raphia palm sap.

Palm sap uses

According to Francisco and Zona (2013), Palm sap may contain 10–20% sugar, this is largely dependent on the species, year time, and the method of extraction. Depending on local demands (and the availability of alternatives), customs, and markets, sap can be used for any of these five purposes after it has been gathered. Fresh sap that has not been fermented is heated to create syrup or molasses (also known as honey) or is further processed to create sugar. As an alternative, palm sap can be brewed into palm wine or consumed fresh or mildly fermented (sweet toddy). Spirits can be made by distilling palm wine. Finally, acetic acid bacteria can ferment the fermented sap to generate vinegar (Francisco and Zona, 2013). In tropical environments, if palm sap is not refrigerated or preserved with the use of non-sterile implements, fermentation can scarcely be avoided. To reduce fermentation, the sap is typically collected twice or more daily, and anti-microbial substances are added to the collecting vessel. The anti-microbial agents may be lime or crushed dried leaves and/or the bark or wood of certain trees (Francisco and Zona, 2013). The collecting vessels are kept clean and sometimes may involve treatment with lime or smoke.

Fresh sap if not filtered or refrigerated spoils quickly and because it's costly to refrigerate the sap and also maintaining fresh sap at the optimum temperature during transport and marketing is not possible, fresh sap is essentially a product confined to local markets. At ambient temperatures Sugar, syrup and vinegar are relatively stable and thus available in local, regional, and sometimes international markets. Fermented palm sap is a natural source of yeast which is used in leavening bread, (Brady & McGrath, 2010), but this is a highly local use.

Palm sap use has been affected by market forces throughout the world. For example, palm sap has been replaced by Sugar cane as a source of sugar in some parts of the tropics. As cultures change, some products of palm have fallen into disuse. For example, *Phoenix canariensis* sap has historical records of being used for wine production, but nowadays, it is used only for syrup or as a non-alcoholic fresh drink.

Use for Culinary Purposes

Palm wine can be used in cooking, for example, it may be used as a substitute for yeast in food preparations to leaven them (Amadi, 2022).

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Treatment of the eyes
Eye specialists Generally speaking, avow yeast is quite good for the eyes. Therefore, palm wine is suitable for enhancing vision because it contains yeast (Amadi, 2022).

Treatment of malaria
During material assaults, fresh palm wine is frequently blended with local herbs and consumed by local treatment adherents (Amadi, 2022).

Production of milk in mothers who are lactating
Fresh palm wine is typically consumed by lactating women who seek to increase their breast milk supply. Therefore, the bulk of users of palm wine will benefit more from the prevention of fermentation (Amadi, 2022).

Biochemical constituent of palm wine.
Palm wine has a distinctive white colour and a sweet and acidic flavour. According to Santiago-Urbina and Ruiz-Teran (2014), palm wine is made by fermenting the sugary sap of the palm tree using a natural lactic-alcoholic-acetic process. The fermentation process involves an initial lactic acid fermentation, a middle alcoholic fermentation and a final acetic fermentation (Santiago-Urbina and Ruiz-Teran, 2014). At each phase, the microbial activity helps the activity of the microorganism in the next phase. As a result, each cell in the mixture reacts to the presence of others in the microbial environment (Smid and Lacroix, 2013). A decrease in the pH and an increase in the total acidity as a result of organic acids produced probably improves the growth and activity of invertase of the yeasts, and the ethanol produced by the yeasts serves as a substrate for the production of acetic acid by the acetic acid bacteria (Santiago-Urbina and Ruiz-Teran, 2014). The palm sap is transparent and has a sugar content range of approximately 10-18% w/v, which is mainly sucrose (Santiago-Urbina *et al.,* 2013), for example, it was reported the sap of Phoenix dactylifera contains sugars in the proportion of 95.27% of sucrose, 2.51% glucose and 1.61% fructose (Ben-Thabet *et al.,* 2009). Palm sap has a pH of approximately 7 to 7.4; a pH that is near neutral, the freshness of the palm sap is shown by this value (Santiago-Urbina *et al.*, 2013). As a result of tapping, the translucent palm sap turns whitish (Santiago-Urbina and Ruiz. Teran, 2014). The sap also has a milky white hue due to the yeast and bacteria present. According to Santiago-Urbina and Ruiz.Teran (2014), the composition of palm wine depends on the stage of fermentation at which it is being consumed. Table 2. And 3. shows the composition of fresh and fermented palm sap respectively.

Odorants of palm wine
As a result of microbial metabolic activity rather than palm tree metabolites—the major components of which cannot be found in fresh palm sap—a variety of organic acids and alcohols are produced during the fermentation of palm wine, all of which are crucial to the wine's distinctive aroma (Santiago-Urbina and Ruiz. Teran, 2014). For example, in *Elaeis guineensi* palm wine, 73 compounds have been identified. There are 23 esters, 14 alcohols and phenols, 11 carbonyls, 10 acids, 5 sulphur compounds, 3 terpenes, 2 acetals, 2 hydrocarbons, 2 nitrogen compounds and 1 lactone. The main volatile components that give palm wine its aroma are the higher alcohols and esters (more than 70% of total volatiles), as well as acids, aldehydes and ketones, are the major class of compounds detected (Santiago-Urbina and Ruiz. Teran, 2014). Related to this, is the work reported by Lasekan *et al.* (2007), their finding showed that the palm wine volatile profile is largely dominated by alcoholic substances such as ethanol, 2-3-methylbutanol and 2-phenylethanol, as well as acetic acid. In addition, ethyl butanoate, acetoin, diethyl succinate, ethyl lactate have also been reported, and several acids such as isobutanoic acid, 2-methyl butanoic acid, 3-methylpentanoic acid, phenylacetic acid and pentanoic acid. The most potent odorants in palm wine are earthy-smelling: 3-isobutyl- 2metoxipyrazine, buttery-smelling acetoin, fruity ethylhexanoate, 3-methylbutylacetate and popcorn- smelling 2-acetyl-1-pyrroline. Furthermore, Nur Aimi *et al.* (2013) identified the volatile compounds responsible for the aroma in fermented nipa sap (Nypa fruticans), which includes alcohols such as ethanol, 1-propanol, 2-methylpropanol, 2-methylbutanol; acetoin, acetic acid, diacetyl, and esters such as ethyl acetate and ethyl lactate.

Palm wine Microbiota
According to reports by Ogu *et al.* (2022) and Chandrasekhar et al. (2012), local drinks including palm wine, burukutu, pito, fura, and nunu are excellent sources of Saccharomyces cerevisiae. They contain nutrients such as amino acids, proteins, vitamins, and sugars, among others (Ogu *et al.*, 2022). Thus, the beverages become true substrates for the growth of a variety of microorganisms. In Nigeria, these beverages are both produced and consumed in enormous amounts (Agwuna *et al.*, 2019). Indeed, numerous studies have been conducted to isolate and use the yeasts from various regional beverages for industrial

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uses (Ogu *et al.*, 2022; Umeh *et al.*, 2019; Umeh et al., 2015; Brooks, 2008).

Djeni *et al.* (2020) in their research, found that the nutrient-rich palm sap supports a diverse microbiota that includes both the resident flora and the invading flora brought by insects, palm sap collection containers, and tappers. The palm tree species and the region's geography have the biggest effects on the local flora (Bi *et al.*, 2019). The sugars in the palm sap are fermented by this broad array of yeast and bacterial populations (Amoa-Awua *et al.*, 2007; Stringini *et al.*, 2009; Karamoko *et al.*, 2012). Many microbes have been isolated and described from palm wines in previous investigations (Ouoba *et al.*, 2012; Stringini *et al.*, 2009; Amoa-Awua *et al.*, 2007).

de la Fuente Salcido *et al.* (2015) supported the cultivable microbiota of M-Tuba and Tepache and specifically named candidate lactic bacteria (LAB) present in these drinks that were able to produce antimicrobial peptides, which collectively could perform food preservative functions.

Nutrient composition and health effect of Palm wine

The nutrient composition of the fresh sap has been reported by several workers (Agambi *et al.*, 2017; Augustine *et al.*, 2013; Obahiagbon *et al.*, 2012; Singaravadivel *et al.*, 2012; Obahiagbon, 2007). The fresh palm sap is composed of sugars, alcohol, proteins, titrable organic acids, vitamins (ascorbic acid, thiamine, riboflavin etc) mineral elements and water (Obahiagbon, 2009).

The health effects of the sap had been documented. According to a report, jaundice, measles, and malaria might all be treated with palm sap. Additionally, it helps nursing mothers' milk flow. The active ingredients in the palm sap responsible for the above roles are yet to be identified (Obahiagbon, 2009).

The active compounds from several medicinal trees' leaves, barks, and stems are traditionally extracted using palm wine. These active elements are then used to cure conditions like stomach ailments, dental yellow fever, pain, and malaria. Children's skin rashes and illnesses including measles, chicken pox, and smallpox are also treated with it (Ojo and Agboola, 2019). Rich in vitamins and trace minerals, palm wine is historically thought to benefit breastfeeding women generally (Lucky *et al.*, 2017). Additionally, palm wine is widely known for its antioxidant capabilities, and rat models have shown that it has health-promoting benefits (Djeni *et al.*, 2020).

In the sap of *R. hookeri*, eleven nutrients that the body cannot synthesise but which the National Academy of Sciences/National Research Council (2001) recommended for the preservation of good health may be found (Obahiagbon *et al.*, 2007a). Obahiagbon et al. (2007a) created a Recommended Dietary Allowances (RDAs) Table as a result of the discovery of the aforementioned substances as well as other dietary components in the sap of the Raphia palm. This table could be used as a nutritional standard for planning and evaluating intake and the level of essential nutrients deemed fit or adequate to meet the requirements for healthy individuals. *R. hookeri* palm sap contains the following elements: Cl, Na, K, Ca, Mg, Fe, Cu, Mn, Zn, P, and N.

Water soluble vitamins, sucrose and protein

Obahiagbon *et al.* (2007b) found three water vitamins (thiamine, riboflavin, and ascorbic acid) in the sap of Raphia palms, with ascorbic acid having the greatest concentration and thiamine, riboflavin, and ascorbic acid, respectively, following. The yeast Saccharomyces cerevisiae, which is present in the sap and is one of the main catalysts of the latter's fermentation, was identified as the source of the vitamins. The following is a discussion of these vitamins' physiological functions and effects on health:

Thiamine

In the oxidative decarboxylation of pyruvic acid, thiamine pyrophosphate, the active form of thiamine, serves as the cocarboxylase. Pyruvic acid builds up as a result of thiamine shortage. With little energy released, some of the pyruvic acid buildup is converted to lactic acid. For pyruvic acid catabolism to proceed via the citric acid cycle and the electron transport chain, thiamine must be present in human nutrition (Obahiagbon, 2009). Beri-beri, a neurological ailment brought on by diets high in carbohydrates but low in thiamine, is a sickness condition caused by thiamine deficiency in human nutrition (Obahiagbon, 2009; Lehninger, 1990).

Riboflavin

One of riboflavin's physiological functions is the formation of a group of flavoproteins known as the prosthetic group. These proteins serve as hydrogen carriers in the oxidation sequences of respiration, releasing hydrogen into the electron transport chain where it subsequently combines with oxygen to form water. Angular stomatitis, cheilosis, seborrhea, and photophobia are some of the symptoms of riboflavin deficiency (Obahiagbon, 2009).

Activation energy of thiamine and riboflavin

Obahiagbon *et al.* (2007b) revealed the activation energies of thiamine and riboflavin isolated from the sap of the Raphia palm. The calculated activated energies for the vitamins (thamine and riboflavin)

extracted from the Raphia palm sap were 4.0 ± 0.1 and 32.0 kJmol $^{-1}$± 0.1 respectively.

Ascorbic acid

Ascorbic acid has numerous health advantages, including the development of collagen in blood vessels, teeth, bones, and connective tissue. It might help to increase infection resistance. Scurvy (the disintegration of skin, blood vessels, and teeth) is an ascorbic acid deficiency illness (Obahiagbon, 2009).

Sucrose

Obahiagbon and Osagie (2007) revealed the results of a study on sucrose production by Raphia palms, which demonstrated that sucrose is the main sugar found in the sap of *R. hookeri*. The presence of sucrose contributes to the sap of the Raphia palm's sweet flavour. By being oxidised in the cells, carbohydrates are used as one of the main sources of biological energy in humans. Additionally, carbohydrates serve as organic precursors for the production of numerous cell compartments. Sucrose is a macronutrient that provides a rapid source of energy and is regarded in human nutrition.

Protein

According to Ndom (2003), there is relatively little protein in the sap of the Raphia palm. The role of its essential and non-essential amino acids as building blocks in protein biosynthesis, not only for the growth of babies and children but also for the continuous replacement and turnover of body proteins in adults, is one of the health effects of protein

Consumption.

Tradition fermentation and distillation of raphia palm sap for ethanol Production

The production of ethanol from agricultural feedstock for use as an alternative fuel has attracted worldwide attention because of the depleting fossil fuel sources and volatile petroleum prices in the international market. Many countries are seeking alternative sources of energy that can be produced locally (Ohimain *et al.*, 2012). The sap of the oil palm, Elaeis guineensis, and raffia palm, *R. hookeri*, is naturally fermented to create palm wine.It has been widely noted that the saps of oil palm and raffia contain sugars, primarily glucose and sucrose, which make ideal substrates for the fermentation of yeast and bacteria (Ohimain *et al.*, 2012).

According to studies (Karamoko *et al.*, 2012; Igbibadolor, 2009), the microbial infestation of palm sap, which encourages the multiplication of yeast and bacteria for the conversion of the sugary sap into ethanol, is a spontaneous process. Palm wine yeast produces alcohol in the range of 5.8-8.8%. Alcohol tolerance of fermenting yeast has been generally reported to be in the order of 12%, but some stains of palm wine yeast tolerate 10-20% ethanol (Ohiman *et al*., 2012).

In West Africa, the distillate made from fermented palm sap is referred to as "ogogoro," "kaikai," or "apeteshi." The aqueous by-product from the distillation of ethanol from fermented broth is called stillage, spent wash, distillery wastewater, or vinasse. Stillage production and handling are typically challenging processes in all ethanol production facilities in the world. It has been reported that a typical distillery produces about 13 litres of stillage per litre of ethanol produced (Ohimain *et al*., 2012).

The alcohol content of fermented sap is dependent on the ethanol productivity and tolerance of the fermenting yeast and on the efficiency of the distillation. However in most cases, middlemen dilute the ethanol beverage before selling it to customers. Despite this, reports indicate that ogogoro have alcohol contents of 37.6%, 40%, and 30-60%. The idea of scaling up the traditional beverage ethanol produced from raffia palm as a potential source of fuel ethanol is suggested by the high concentration of ethanol produced using simple equipment. Additionally, the raffia palm has been defined as hapazanthic, which means that after a time of vegetative growth, it only produces flowers and fruits once before dying and losing a major source of biomass and energy supply. Ethanol produced from sugarcane, corn and raffia palm has been shown to exhibit good engine performance (Tangka *et al*., 2011).

Economic analysis of the palm wine market

Palm wine is an important economic resource in West Africa especially in Nigeria where it is estimated that per capita income from palm wine tapping can equal or exceed Nigeria's per capita income with a production estimate of two million metric tons of palm wine. In Cameroon, palm wine employs three-quarters of the male population in some villages, and a monthly income of 20,000 to 35,000 France (US $71 -24) for small producers (Nwibo *et al*., 2012).

Nwibo *et al*., (2012) observed that the total cost of marketing 600 litres of palm wine was N42, 000.00, as the total revenue was N69, 000.00, and the gross margin was N47, 520.00 The profit of N38,300 was realized from the marketing of 600 litres of palm wine in the area(Idemili North LGA of Anambra state, Nigeria) while the benefit-cost ratio was N1.60 which indicated that that for every N1 spent in the marketing of palm wine, a profit of N0.60k was realized.

Ubokudom and Okorji (2014) in their study of the economic analysis of palm wine observed that the raphia wine production enterprise had an average gross margin of N 226,229.00 (N 37,704.83 per mature raphia palm) and a net income of N 223,244.90 (i.e N 37,204.00 per raphia palm tree) in a production period of two months (8 weeks in the study area). The net income of N37, 204.00 per mature raphia palm tree when divided by the production period of two months gives a monthly income of N 18,602.00. This implies that raphia palm wine production is profitable in the study area. This amount is more than the minimum wage rate (N18, 000) per month in Nigeria. During the fieldwork components of their study, most palm wine tappers expressed a high level of satisfaction with the profit level of the business.

Palm wine cost US$ 2.7/liter at Melgar, Tolima, and US$ 0.8/liter close to El Banco, Magdalena, in August 2009. In the Magdalena Valley, where the fermenting sap is combined with water, the income from a 5–10 m tall palm with an estimated age of 15–25 years ranges from US$ 16–54 in 20 days. The sale of palm wine is a small-scale business that employs few people in each community; the beverage is often sold only at the houses of the makers, never making it to markets. Colombia is not known to produce jaggery from palm sap in the manner used in Asia (Bernal *et al.*, 2010).

Omofonmwan *et al*., (2013) studied the assessment of the palm wine market in Edo state, Nigeria. Their study revealed that the average weekly marketing margin and net profit per 100 liters per retailer were N7, 644.00 and N2, 923.78 as well as N1, 529.00 and N508.36 per wholesaler respectively. Their study showed that palm wine market in the studied area was profitable.

Conclusion

Palm wine is a unique beverage because of the various functions it performs in different circumstances and for this reason should be given more research attention to promote its production and marketing at both local and international markets. With a twenty-four-month shelf life, it has been preserved in its original form. Its sap has been used to make beneficial products that could also meet human needs. The nutritional makeup of the sap points to several functions in human physiology and well-being. Smallpox, chicken pox, jaundice, measles, malaria can all be treated with the sap/palm wine as well as aiding in the flow of mammalian glands in nursing mothers. There should be more research done on the production, preservation, and marketing of palm wine.

Conflict of interest: The authors declare no conflict of interest.

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Table 1: African regions of various names for palm wine.

Local names	Africa region
Emu, Oguro, nnmanya, ngwo	Nigeria
Nsafufuo, doka, akpeteshe	Ghana
Ubusulu	Southern Africa
Malafu ya ngesi (kikongo)	Democratic republic of congo
Mimbo, mtango	Cameroun
Poyo	Sierraleone
Toutou	Gabon
Lagbi	Libya

Source: (Amadi, 2022; Bisi- Johnson *et al.*, 2011)

Table 2: fresh palm sap's composition make-up.

Compounds in palm wine	Quantity
Sucrose (%)	11.2
Glucose (%)	0.95
Fructose (%)	1.0
Raffinose (%)	-
Protein (%)	-
Ammonia (%)	-
Vitamin C mg/100ml	18.6
Vitamin B12 mg/100ml	160
Alcohols (%)	4

Source: Chandrasekhar *et al.*, 2012.

Table 3: Composition of palm sap after fermentation

palm wine compounds	Quantity 100 ml/12hours
Ascorbic acid	16-30
Sucrose	12.3-7.4
Protein	0.23-0.32
Ash	0.11-0.41
Copper	0.286-1.630
Manganese	0.140-0.166
Sodium	50.1-78.2
Calcium	82.3-101.0
Lead	3.1-4.59
Zinc	0.151-0.168
Potassium	669-710
Lithium	1.3-107
Nitrate	23-27.7
Alcohols	5-8%

Source: Chandrasekhar et al., 2012